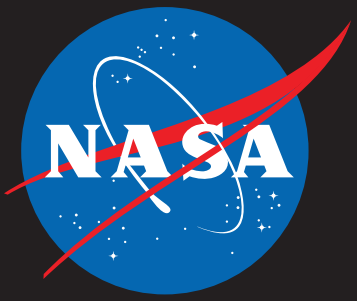
National Aeronautical and
Space Administration



A Multi-Sensor Perspective on the Interannual Variability of Tropical Temperature, Water Vapor, and Clouds

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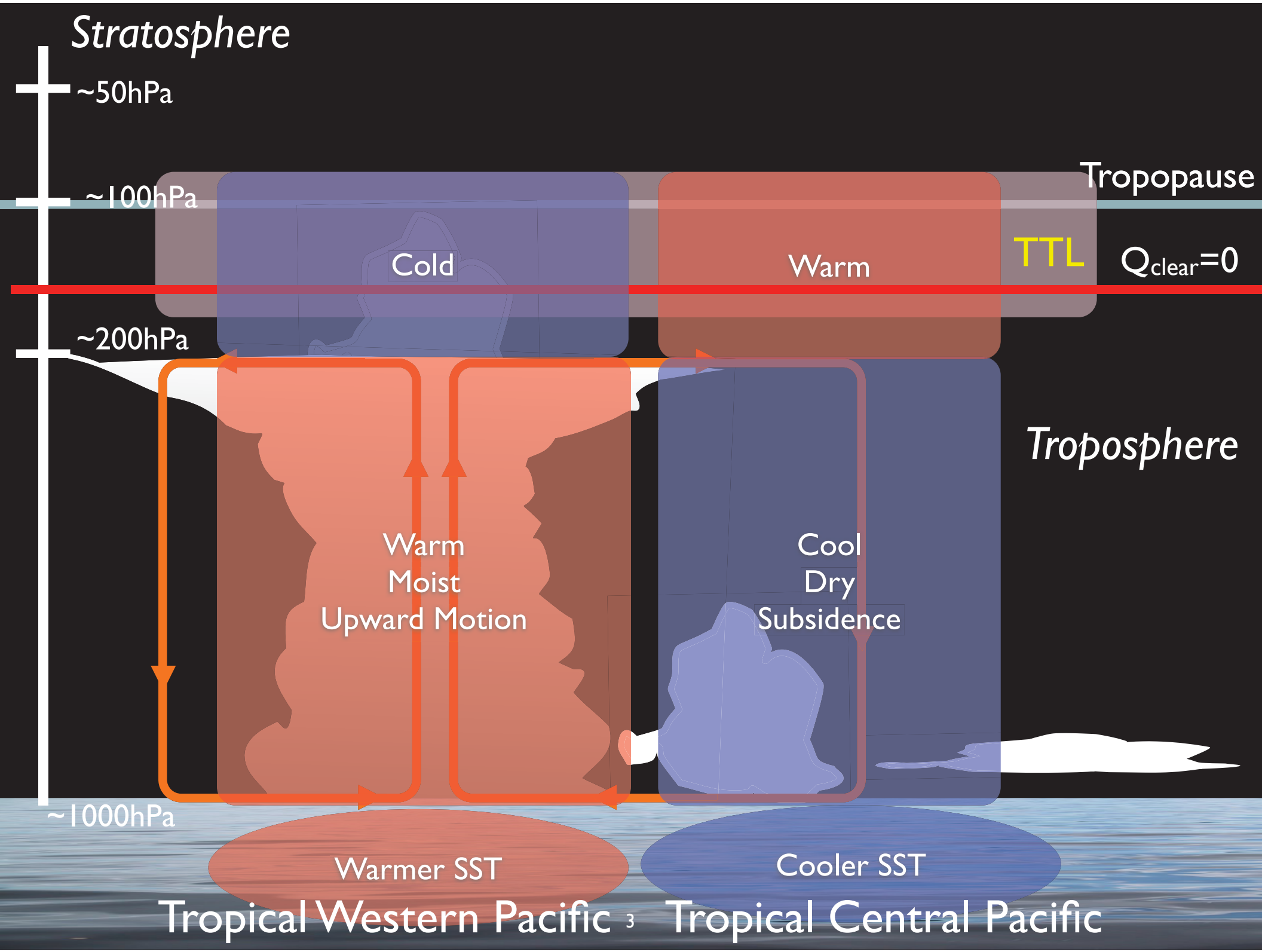
Joint Institute for Regional Earth System Science and Engineering/UCLA
Jet Propulsion Laboratory/Caltech

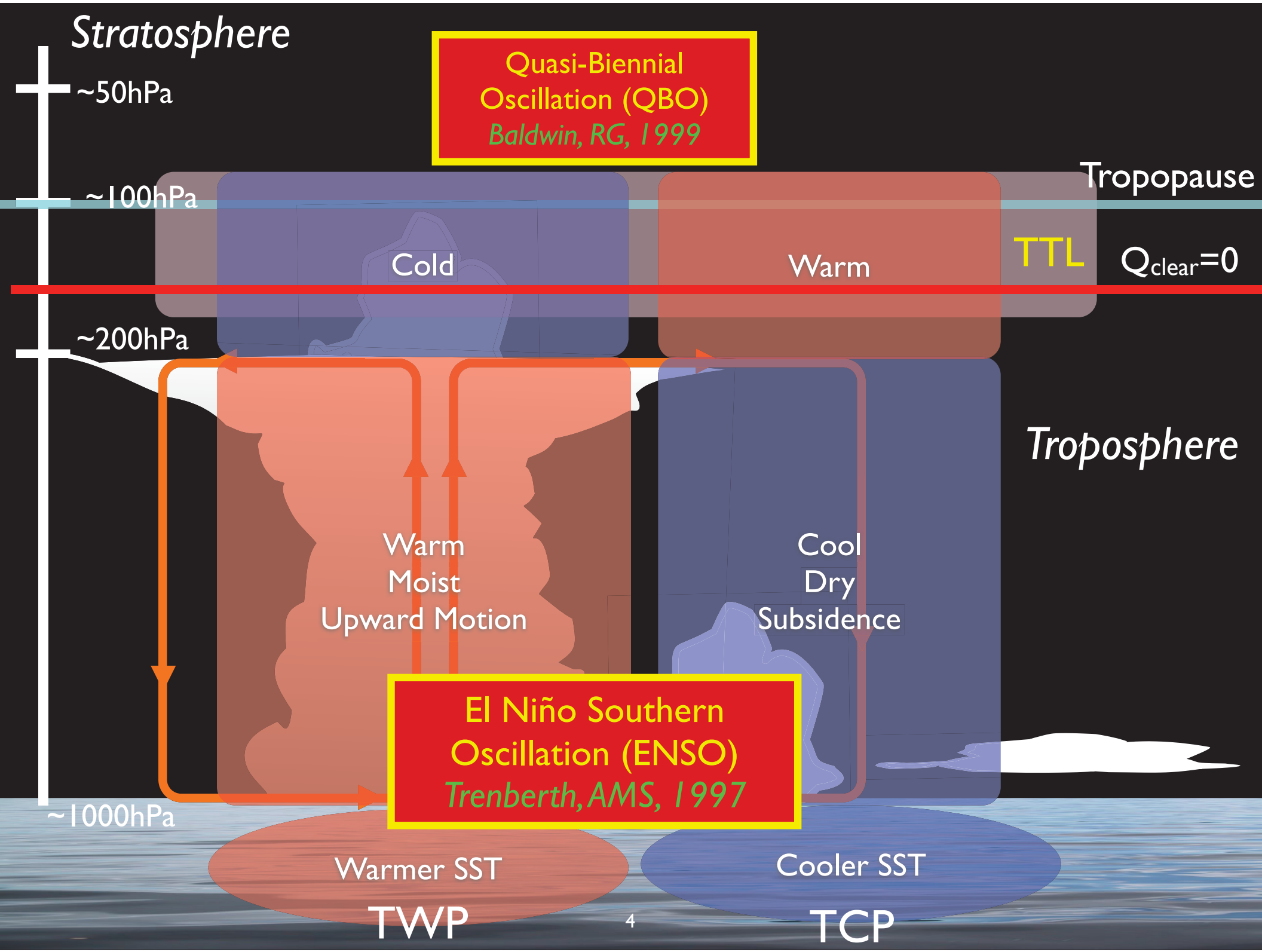
Annmarie Eldering, Andrew Gettelman, Biajun Tian,
Sun Wong, Eric J. Fetzer, and Kuo-Nan Liou

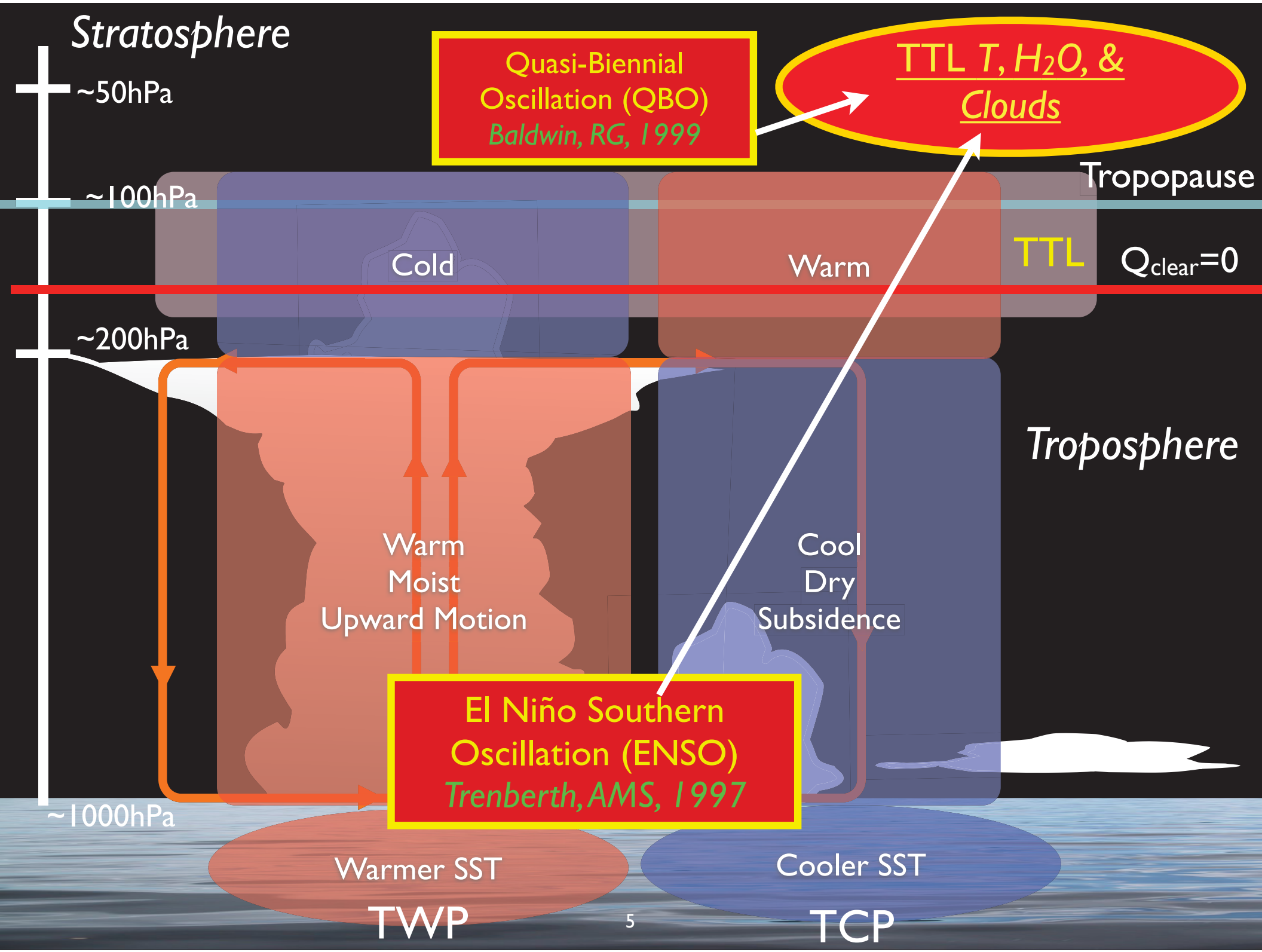
AGU 2010 Fall Meeting
December 17, 2010

Motivation

To better characterize the controls on the tropical upper tropospheric/lower stratospheric (UTLS) temperature, humidity, and clouds.


Stratosphere
~50hPa
~100hPa
~200hPa
~1000hPa
Tropopause
TTL
$Q_{clear}=0$
Cold
Warm
Troposphere
Warm
Moist
Upward Motion
Cool
Dry
Subsidence
Warmer SST
Cooler SST
Tropical Western Pacific
Tropical Central Pacific


Stratosphere
~50hPa
~100hPa
~200hPa
~1000hPa
Quasi-Biennial Oscillation (QBO)
Baldwin, RG, 1999
Tropopause
TTL
Qclear=0
Cold
Warm
Troposphere
Warm Moist Upward Motion
Cool Dry Subsidence
El Niño Southern Oscillation (ENSO)
Trenberth, AMS, 1997
Warmer SST
TWP
Cooler SST
TCP


Stratosphere
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~100hPa
~200hPa
~1000hPa
Quasi-Biennial Oscillation (QBO)
Baldwin, RG, 1999
TTL T, H2O, & Clouds
Tropopause
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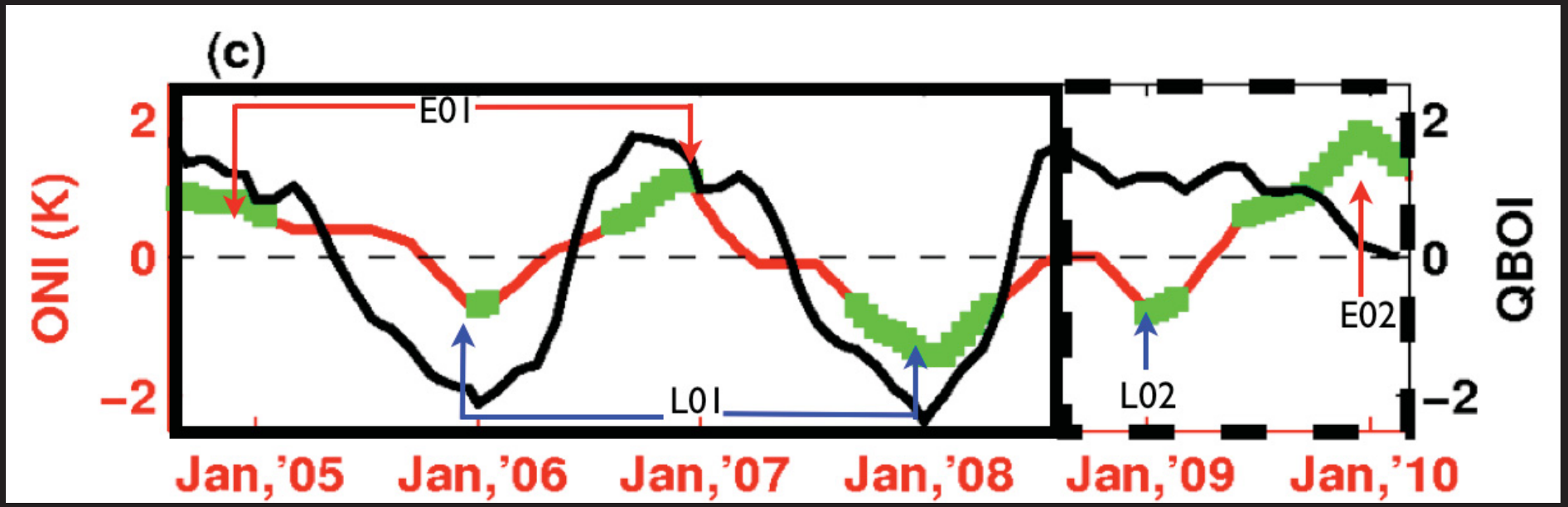
Cool Dry Subsidence
El Niño Southern Oscillation (ENSO)
Trenberth, AMS, 1997
Warmer SST
TWP
Cooler SST
TCP

ENSO and QBO Indices

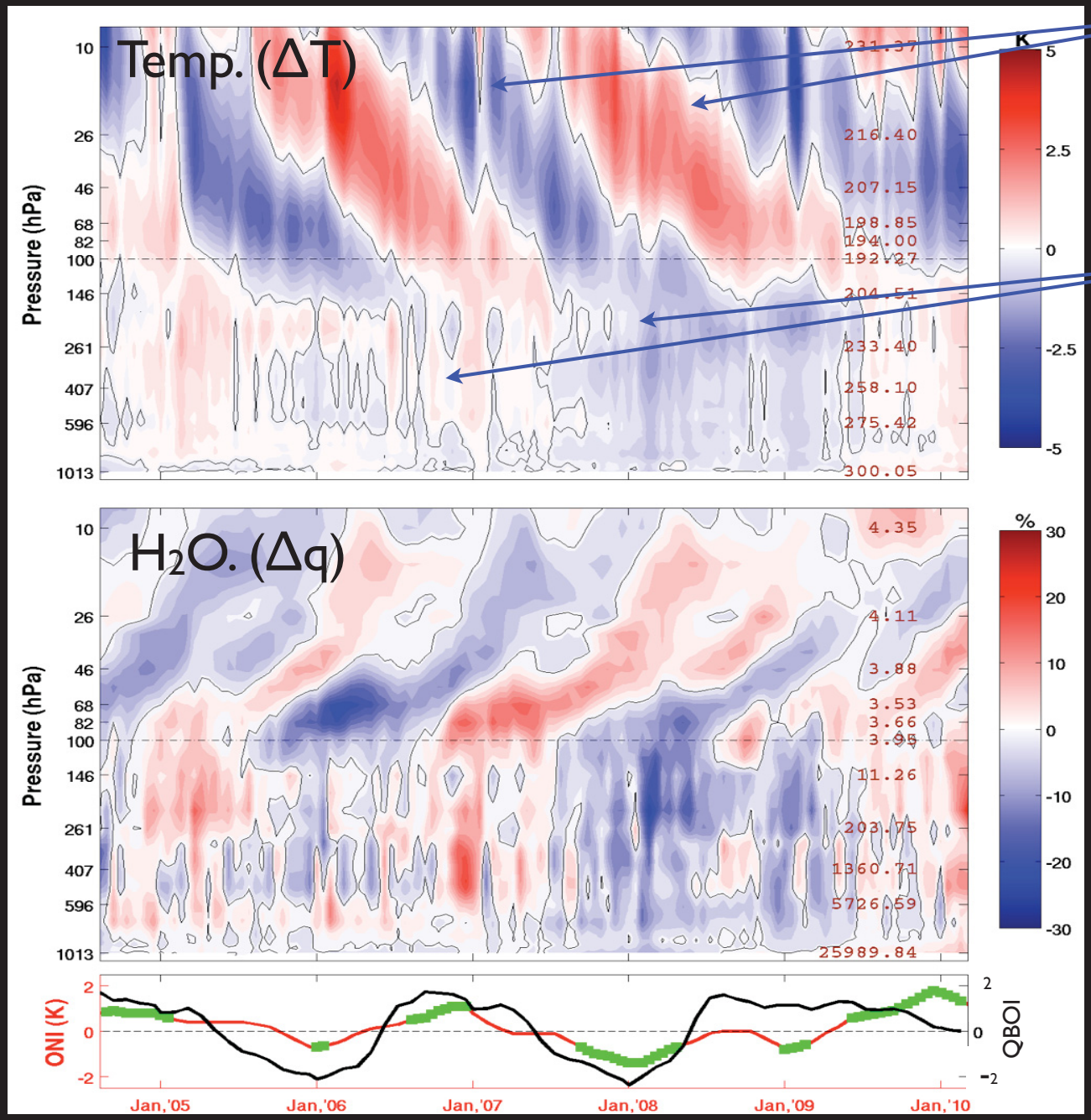


- Ocean Niño Index (ONI) in the Niño3.4 region (5S-5N, 120W-170W) *(Source: NOAA CPC, in-situ measurements)*
- QBOI represent zonal mean zonal wind anomalies at 50 hPa *(Source: NCAR/NCEP reanalysis)*. Anomalies in thermal wind balance with lower stratospheric temperatures *(Randel et.al, JGR, 2000)*

Temperature & Water Vapor (8S-8N)

August 2004-February 2010

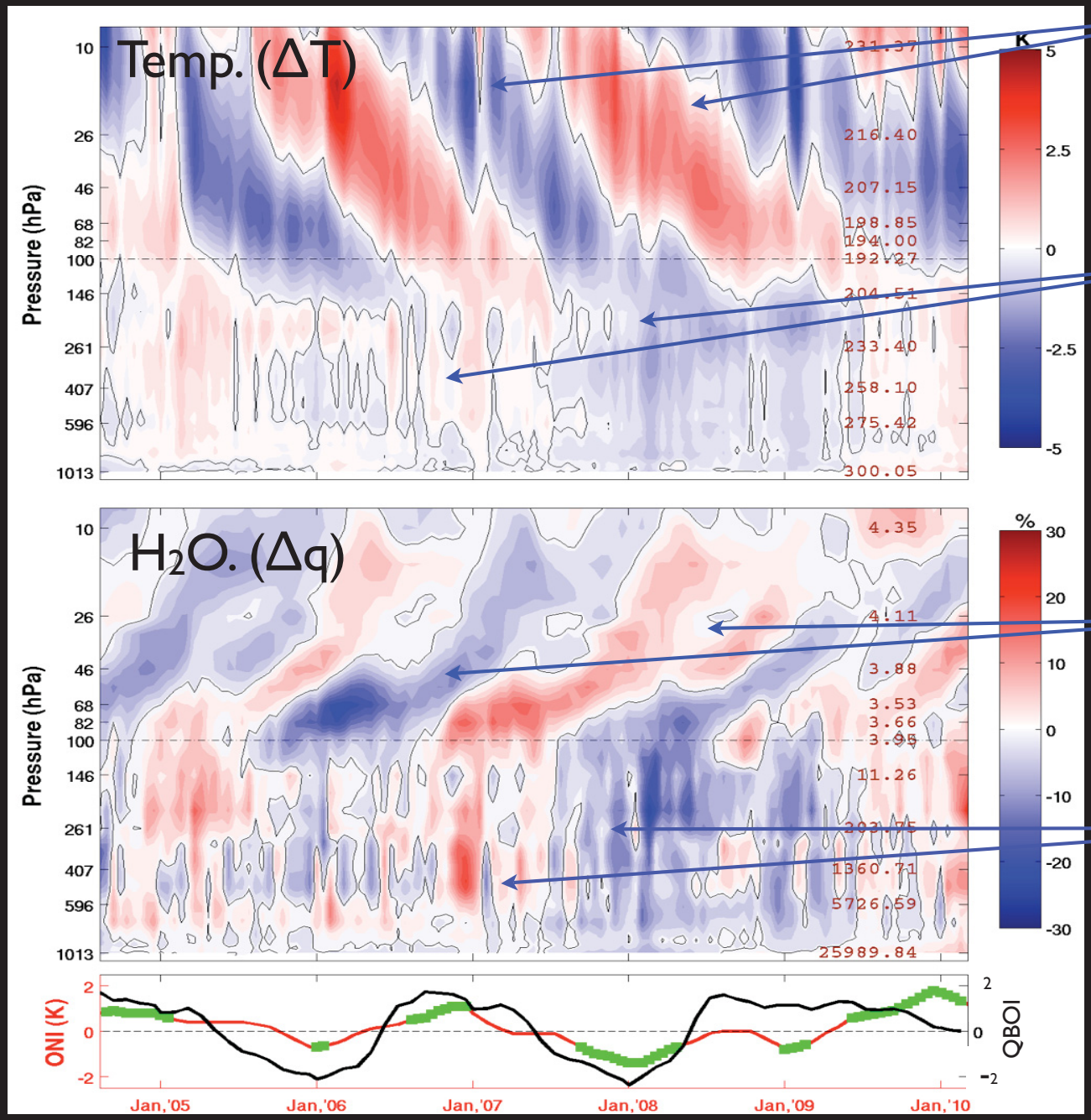
Surface to Stratosphere Interannual Variability of T and H_2O



Quasi-biennial Oscillation (QBO) for T with period ~28 months

ENSO

Surface to Stratosphere Interannual Variability of T and H_2O



Quasi-biennial Oscillation (QBO) for T with period ~28 months

ENSO

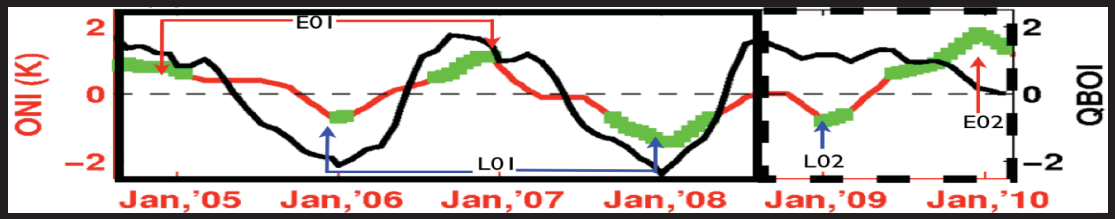
Interannual Variability of tape recorder

(Randel, et. al., JAS, 1998, Gellar, et. al., JAS, 2002)

ENSO

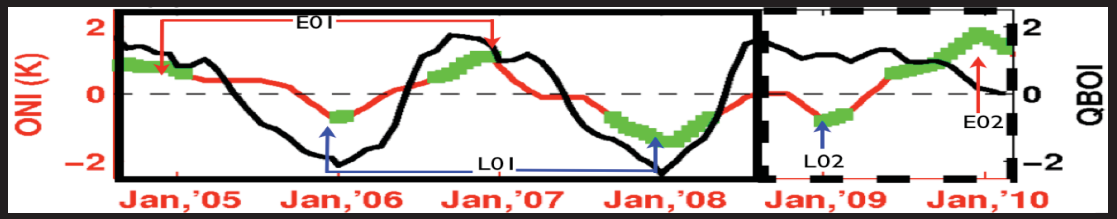
New vertical picture of H_2O

Composites of ENSO events



ENSO Phase
E+ = El Niño
E- = La Niña

QBO Phase
Q+ = Westerly
Q- = Easterly



ENSO Phase
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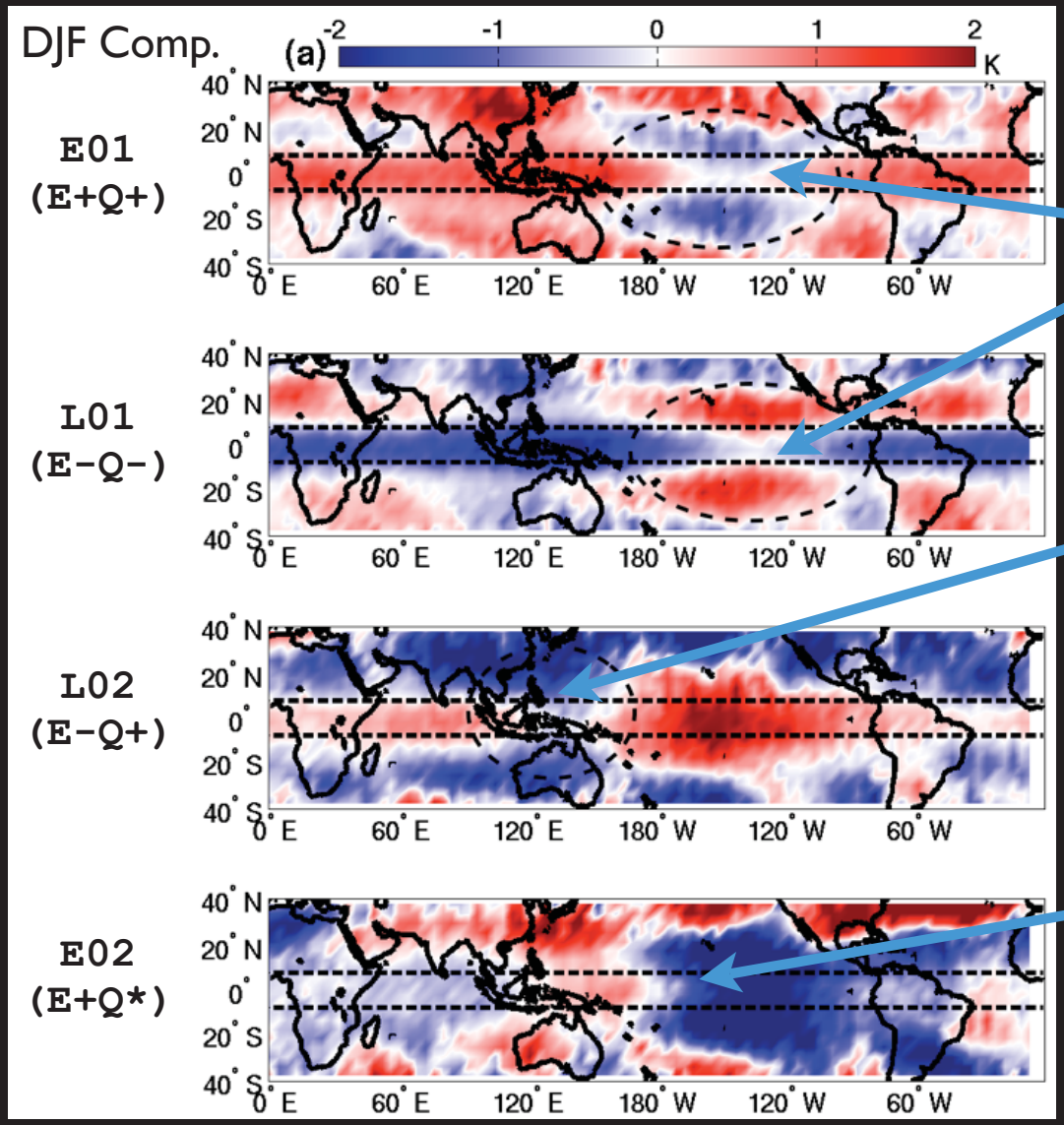
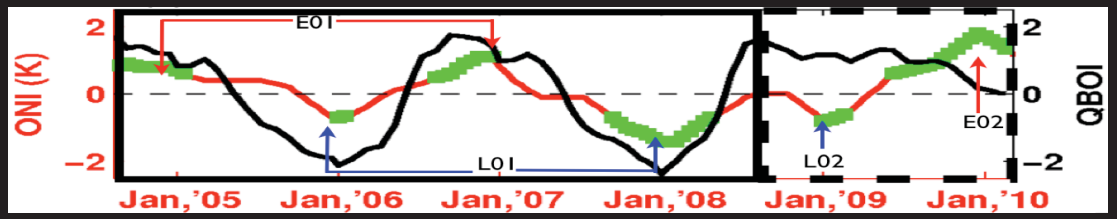
ΔT (100 hPa)



- Zonal break over TCP when QBO and ENSO in phase
- TWP experiences zonal break when ENSO and QBO out of phase
- E02 event primarily an ENSO signal; QBO in transition (Q*)

Liang, et.al, JGR (2010), Manuscript in review



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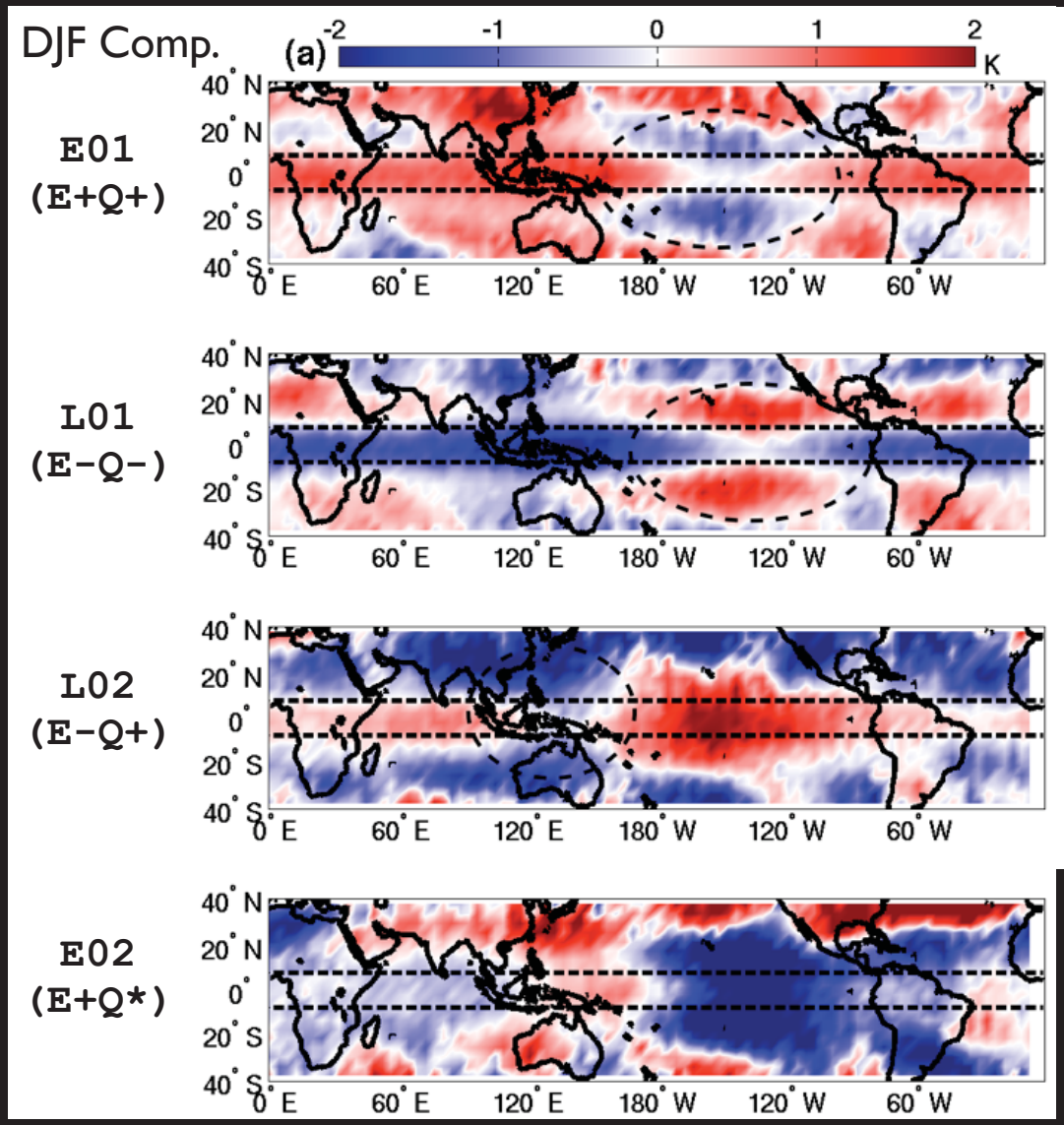
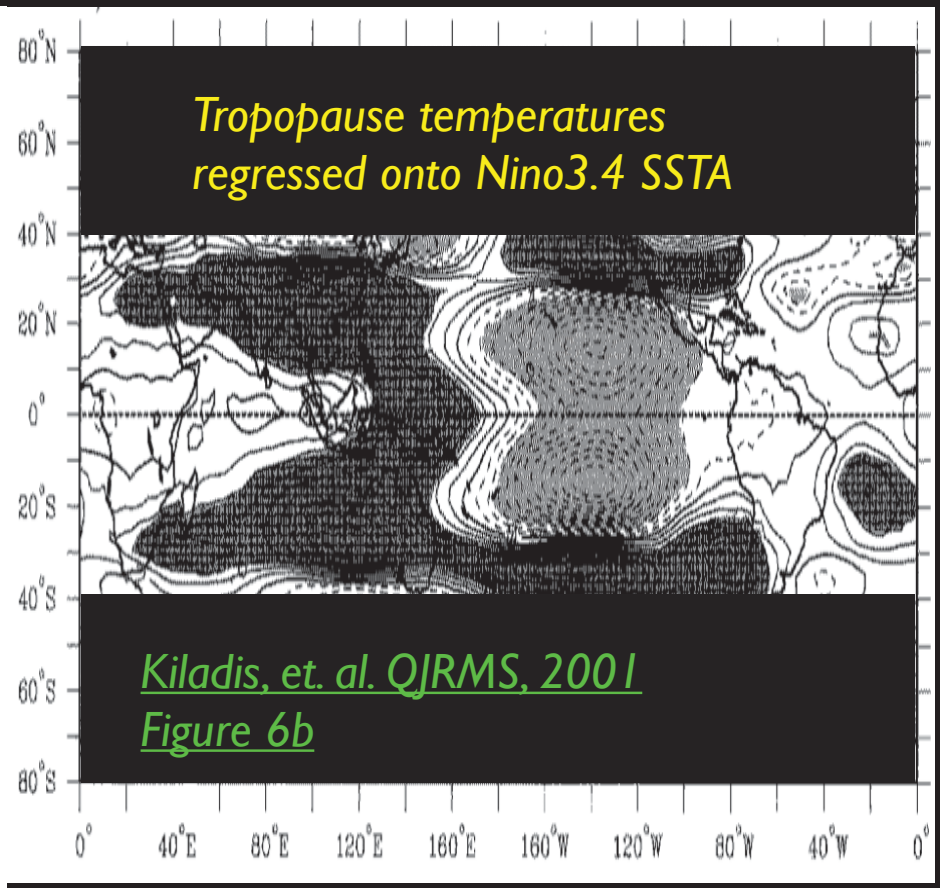
ΔT (100 hPa)

DJF Comp.





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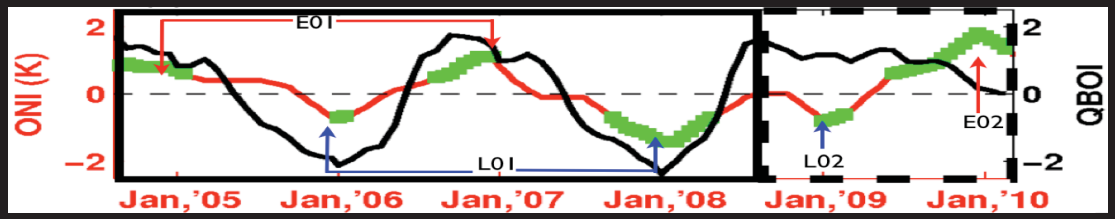

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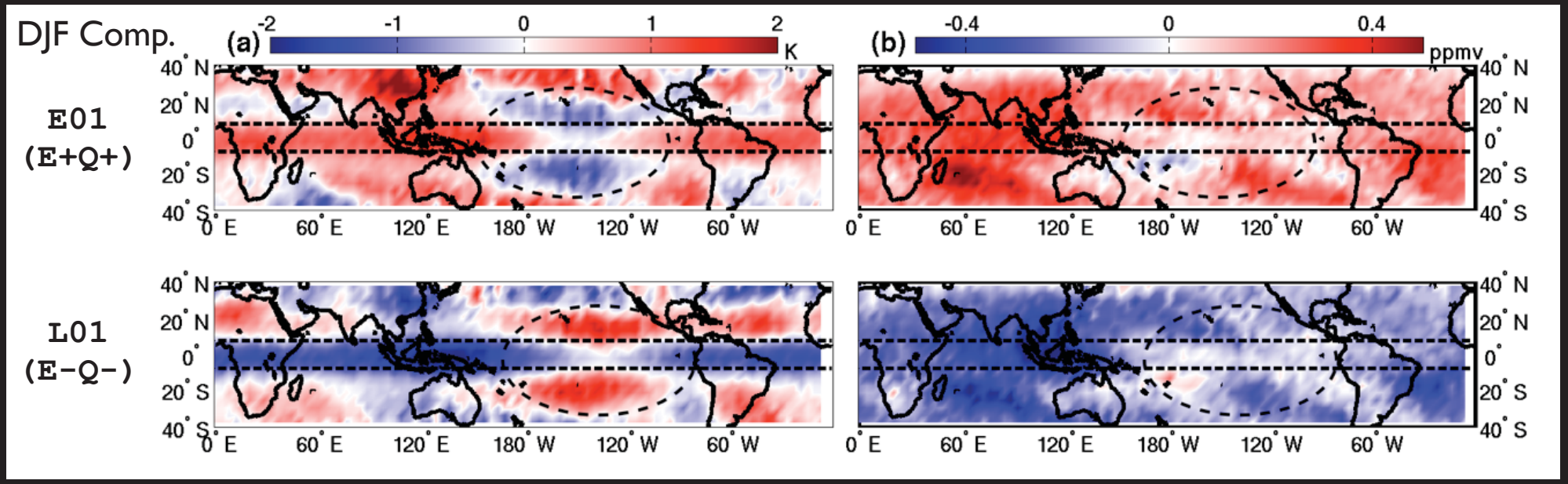
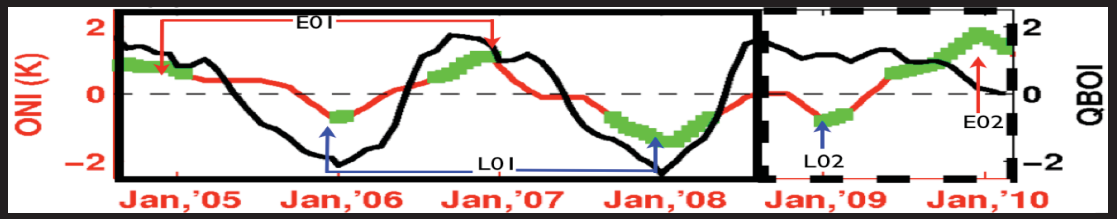
Q- = Easterly

ΔT (100 hPa)

Δq (100 hPa)



Liang, et.al, JGR (2010), Manuscript in review



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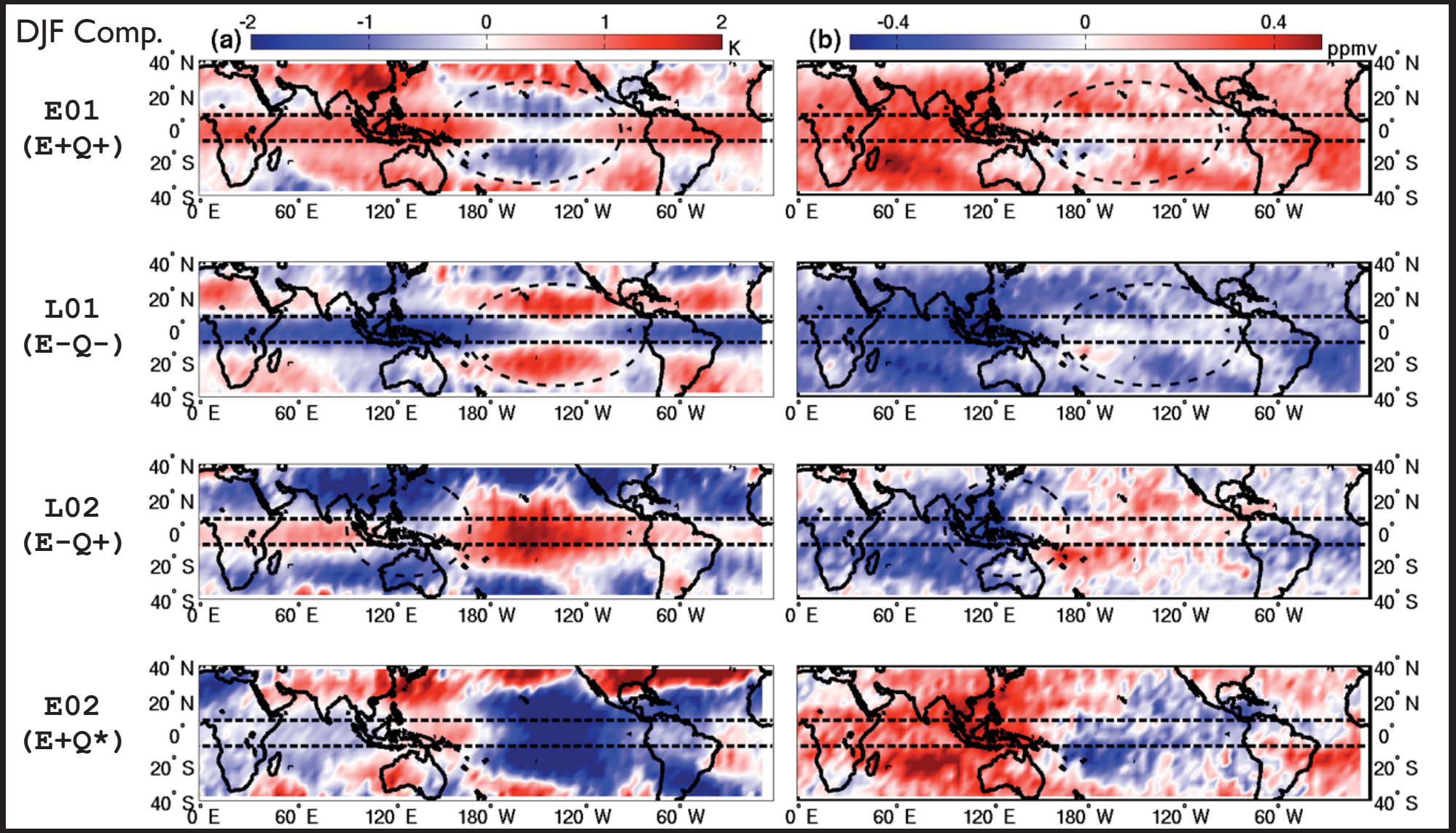
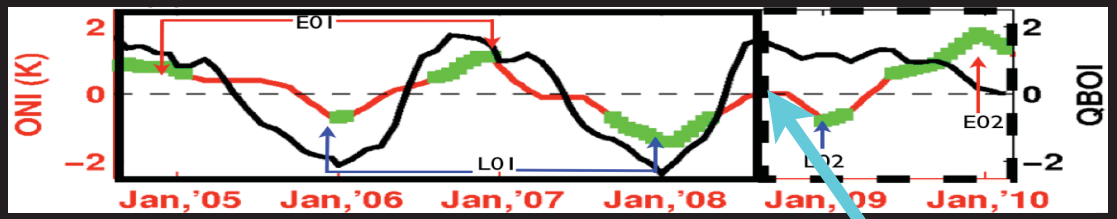
ΔT (100 hPa)

Δq (100 hPa)



Liang, et.al, JGR (2010), Manuscript in review



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ΔT (100 hPa)

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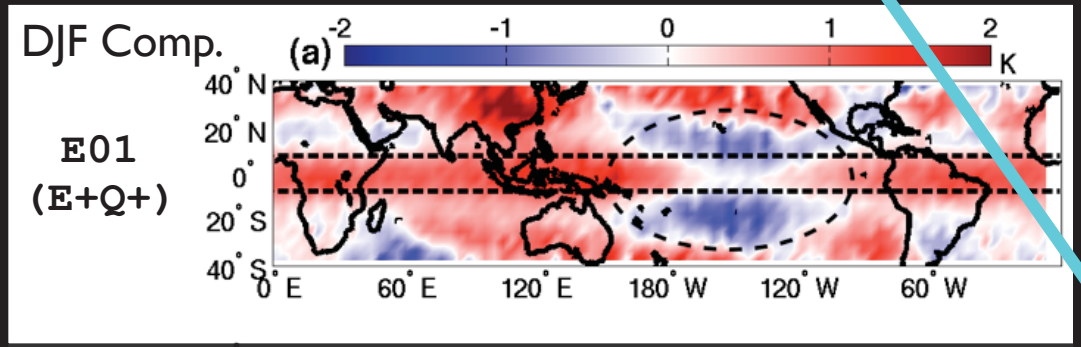
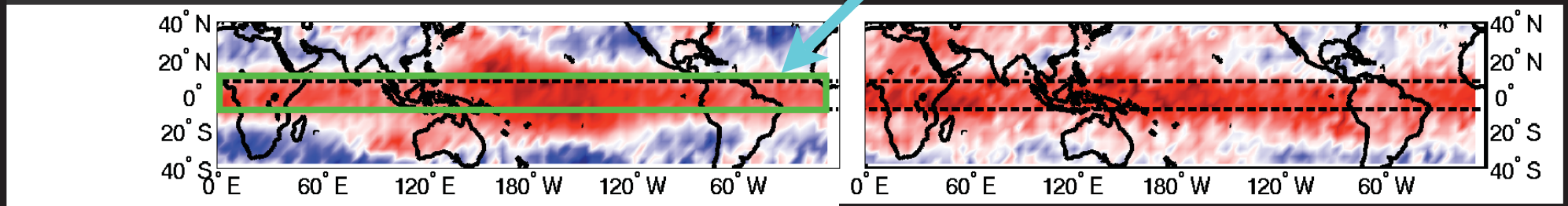
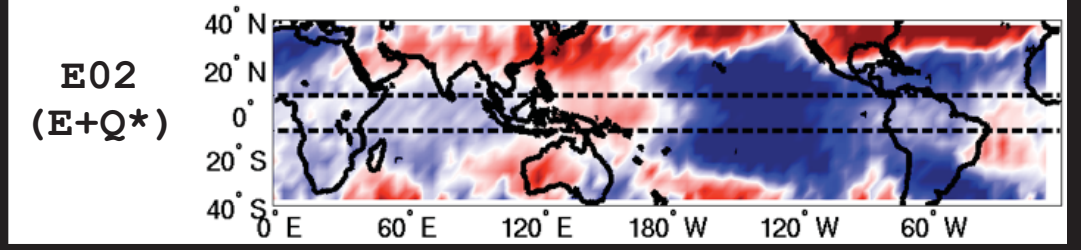


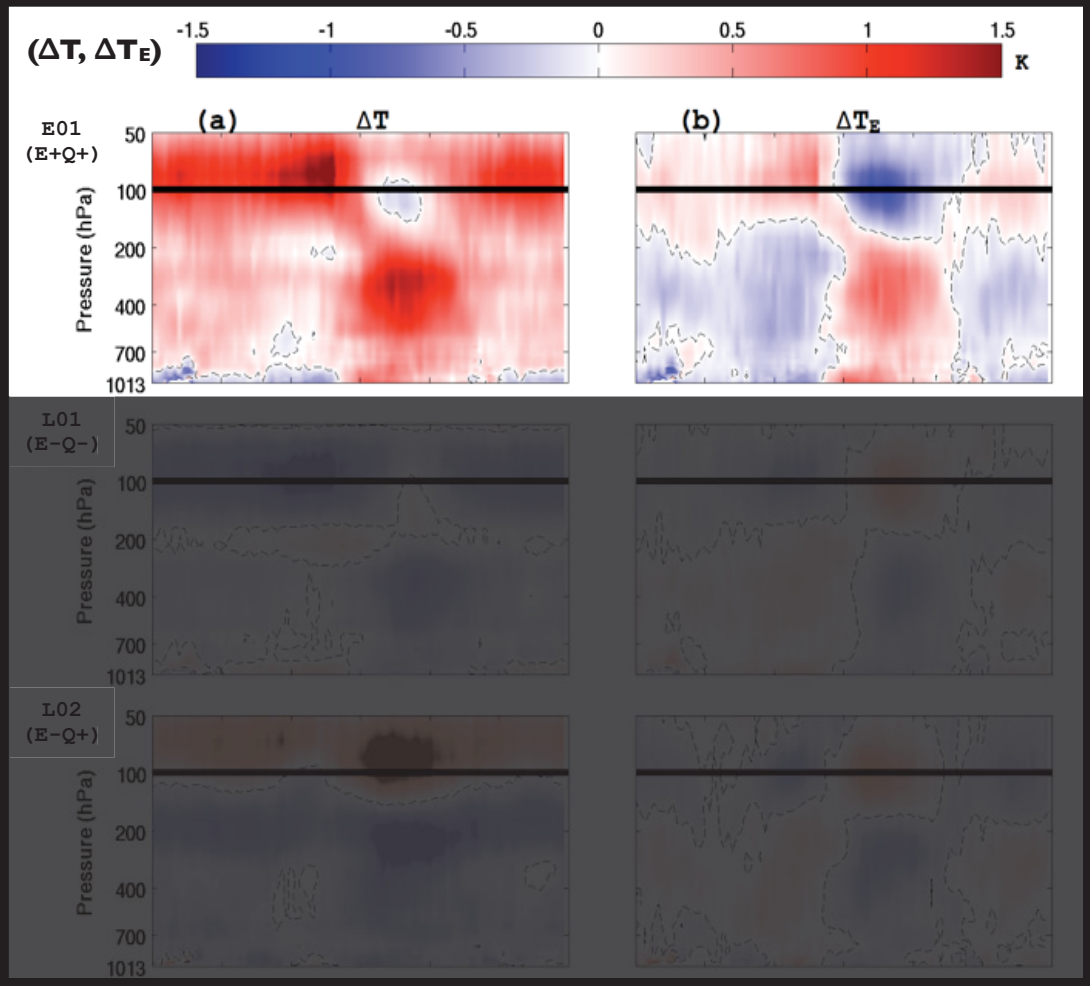
For ONI ~ 0 (~Fall of 2008), and +QBOI we see the zonal symmetry of the QBO

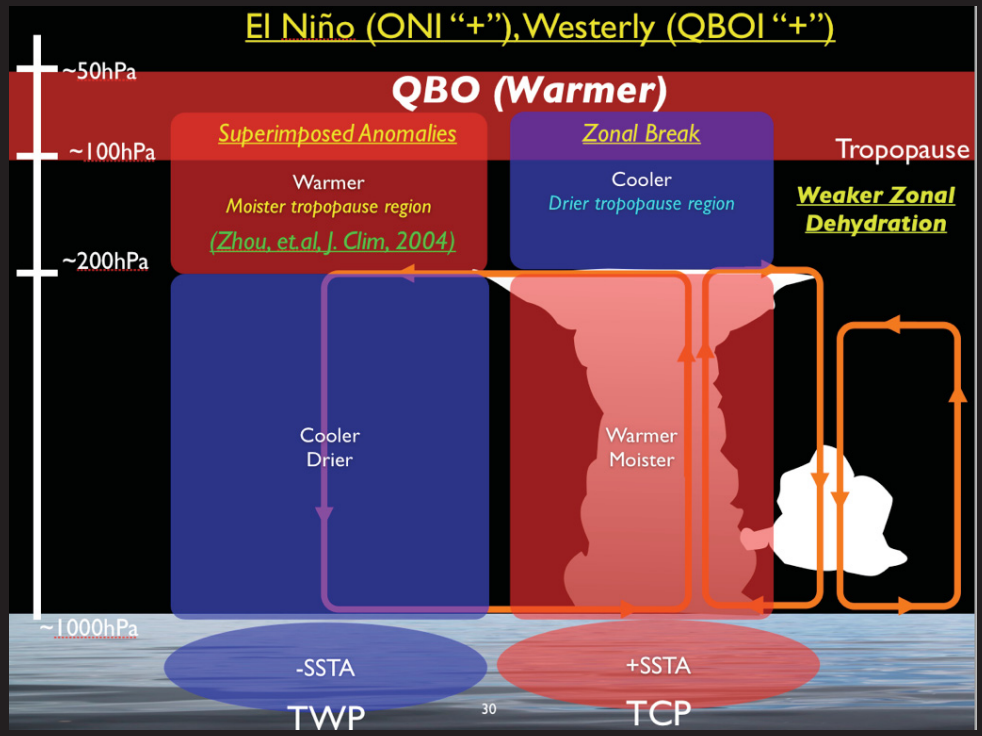




Liang, et.al, JGR (2010), Manuscript in review

Vertical and Zonal Structure of ΔT and Δq





- Zonal break in QBO signal is due to ENSO induces changes in convection
- ΔT_E shows quadrupole structure between TCP and TWP.

Liang, et.al, JGR (2010), Manuscript in review

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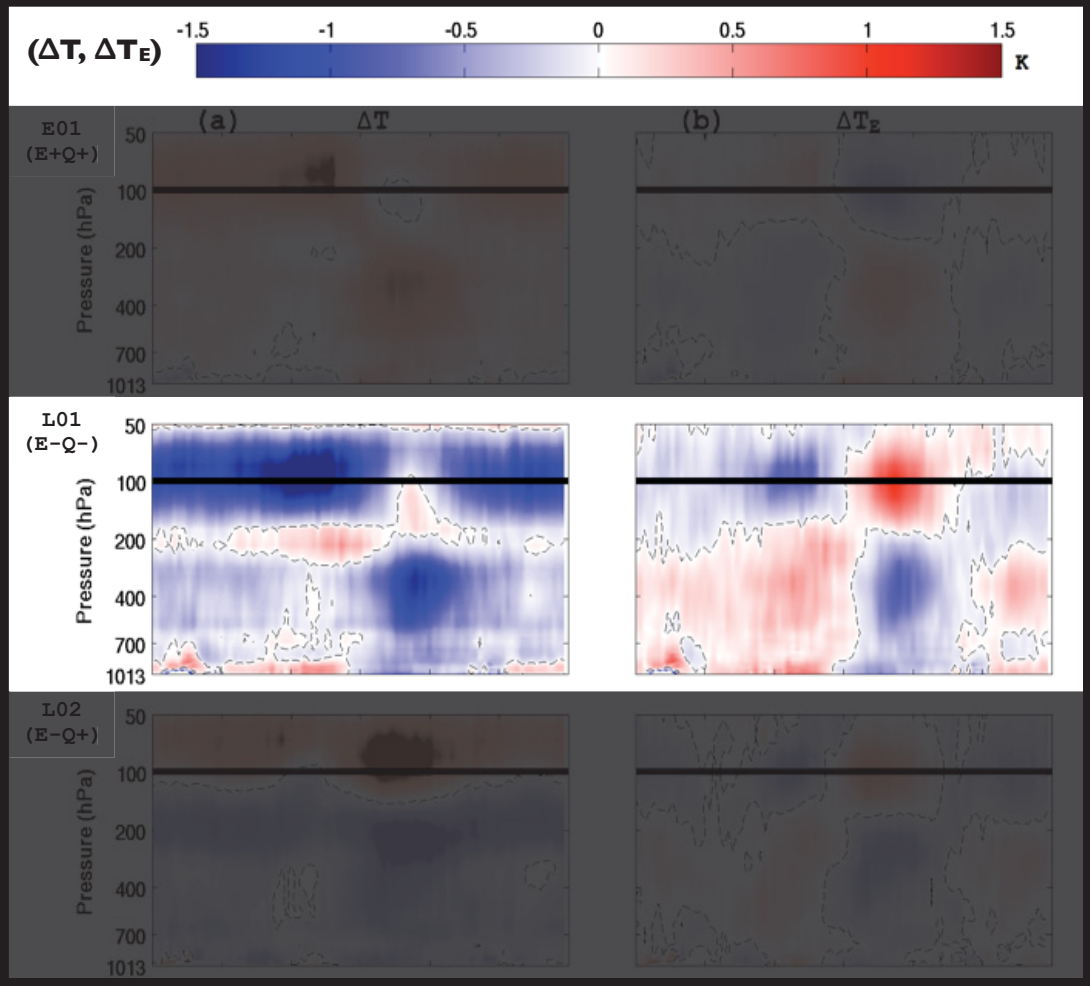

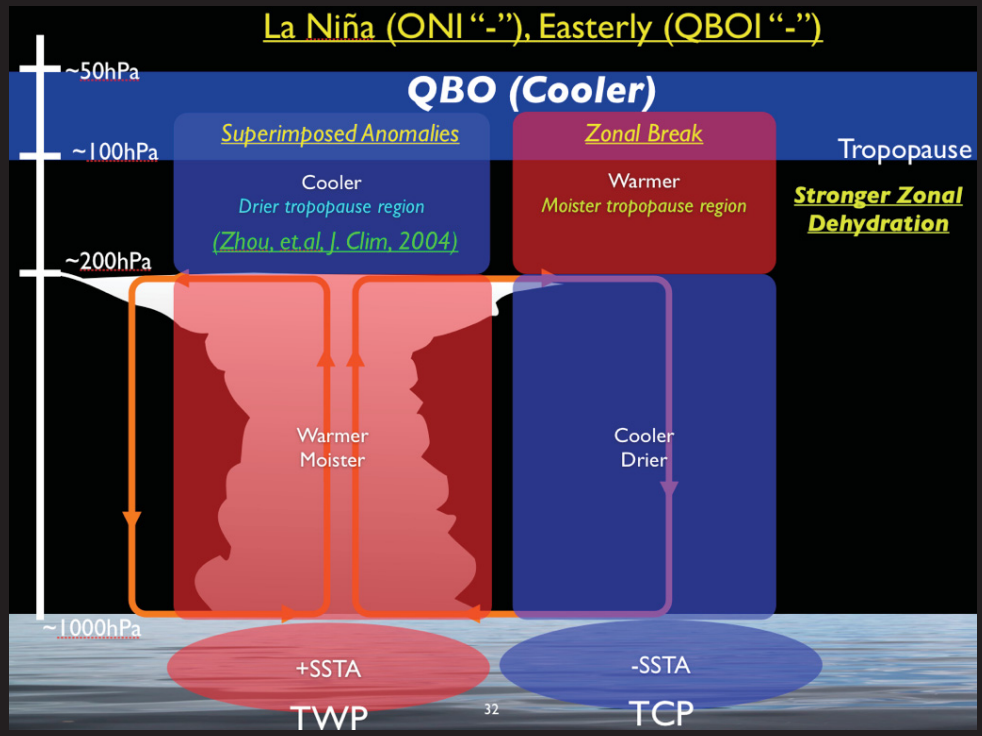

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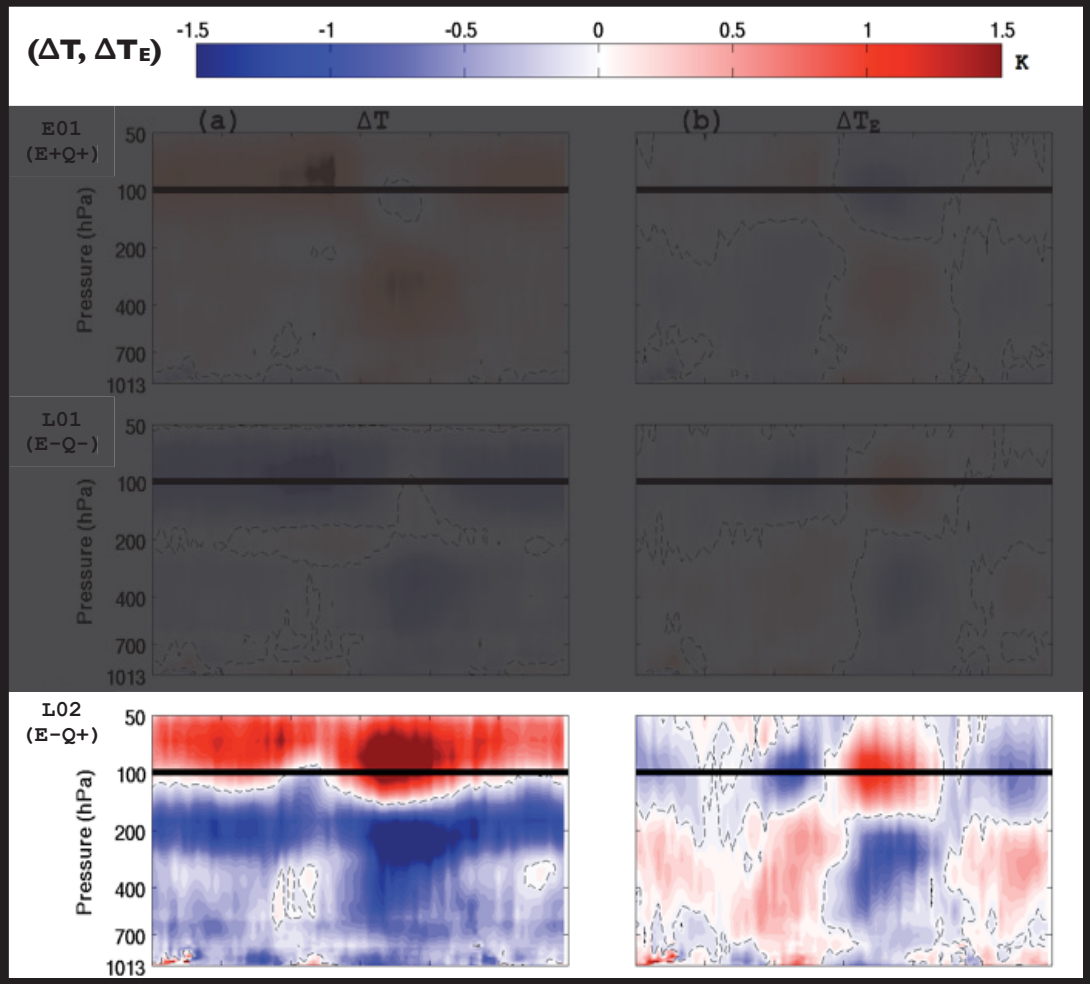

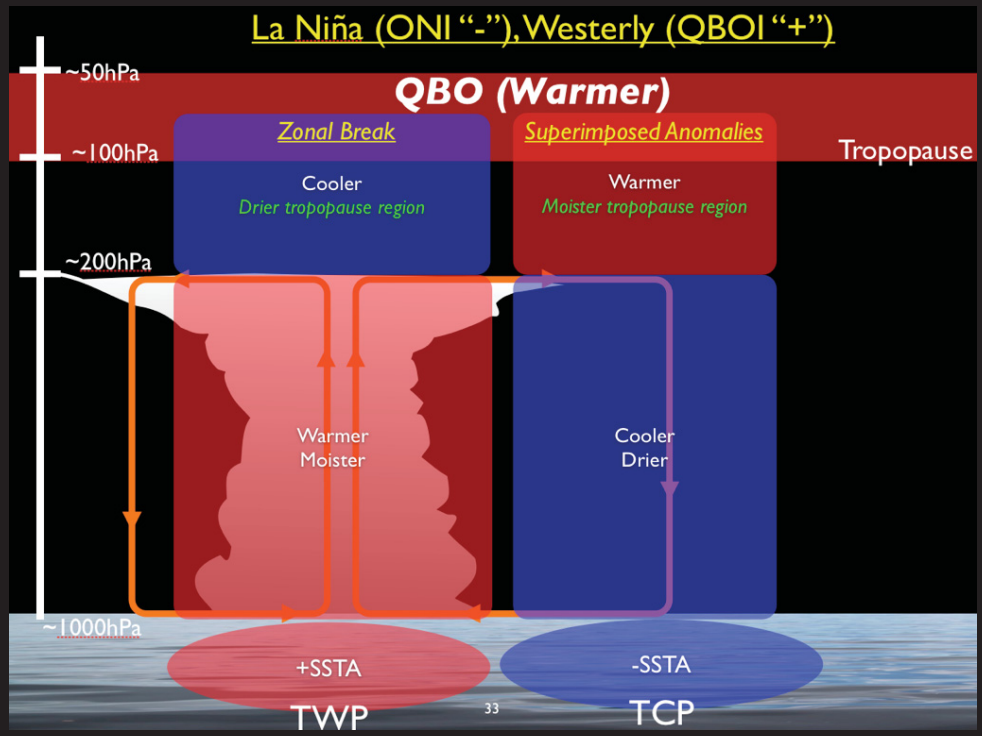

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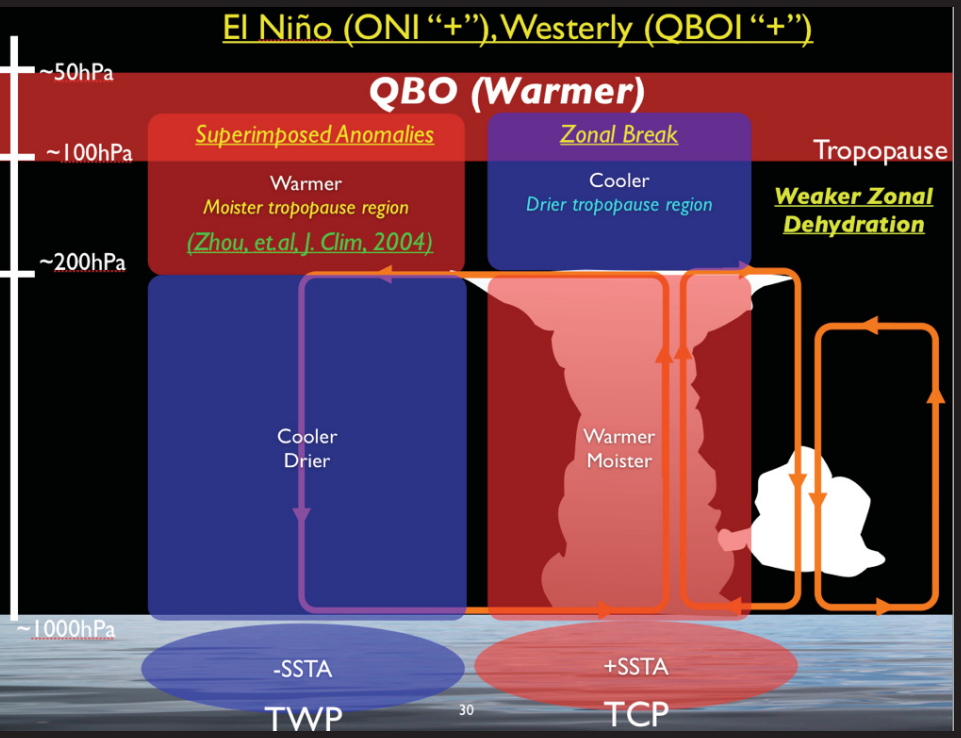

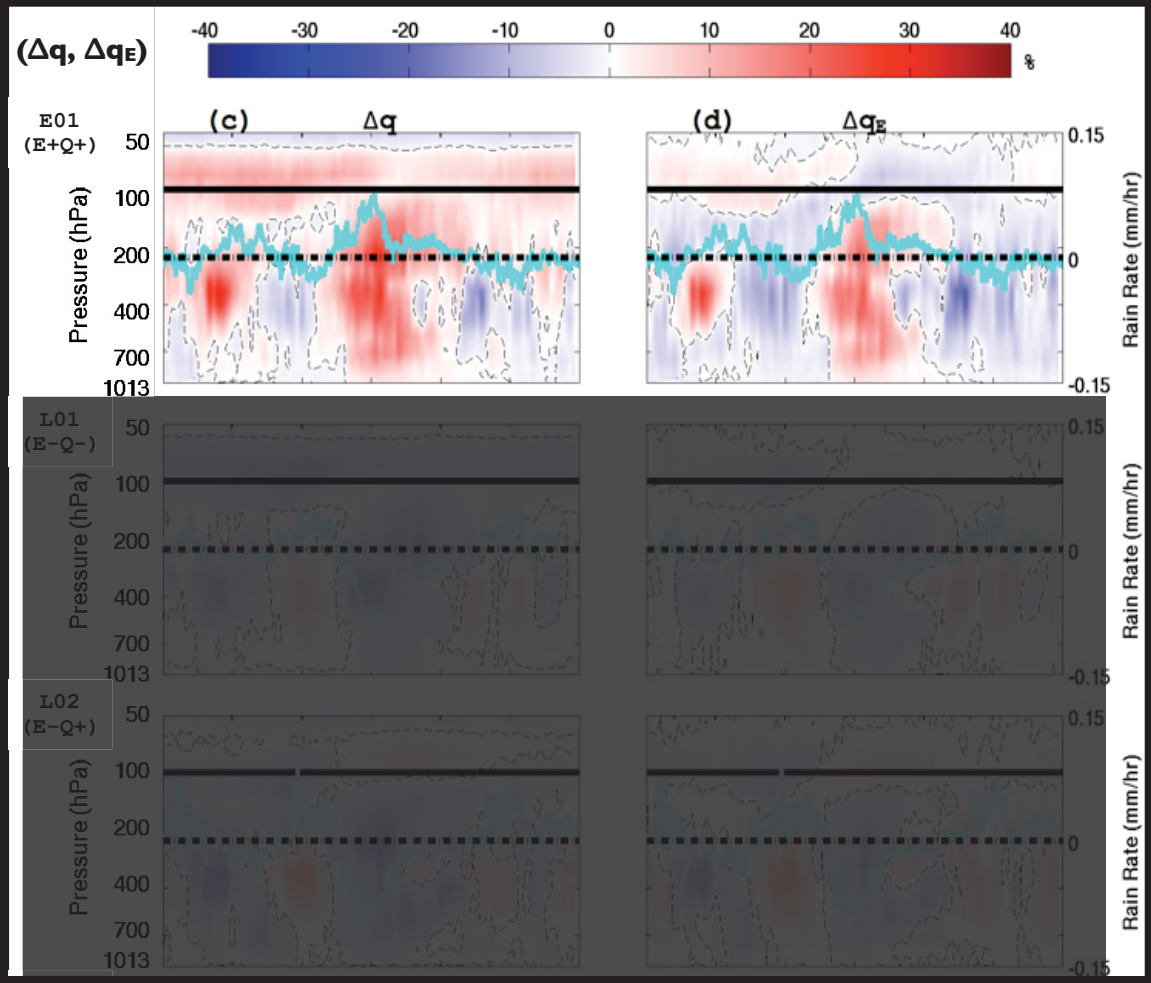

- Moisture and rain rate (TRMM) anomalies track each other
- Δq_E shows moisture also has quadrupole feature like ΔT_E but with different vertical extent

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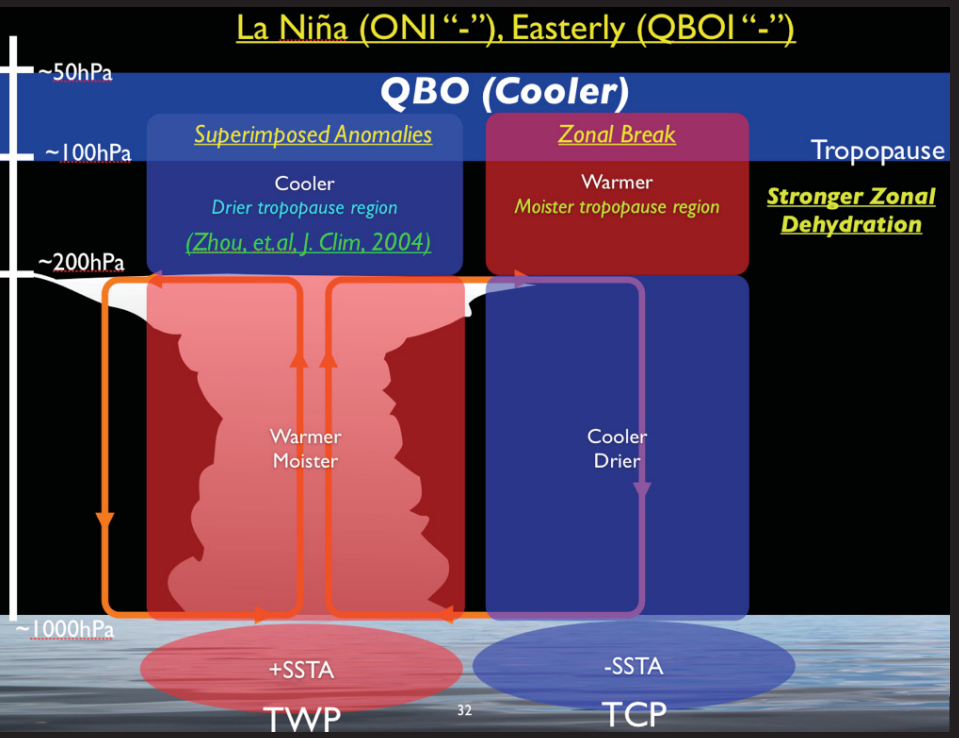
Vertical and Zonal Structure of ΔT and Δq



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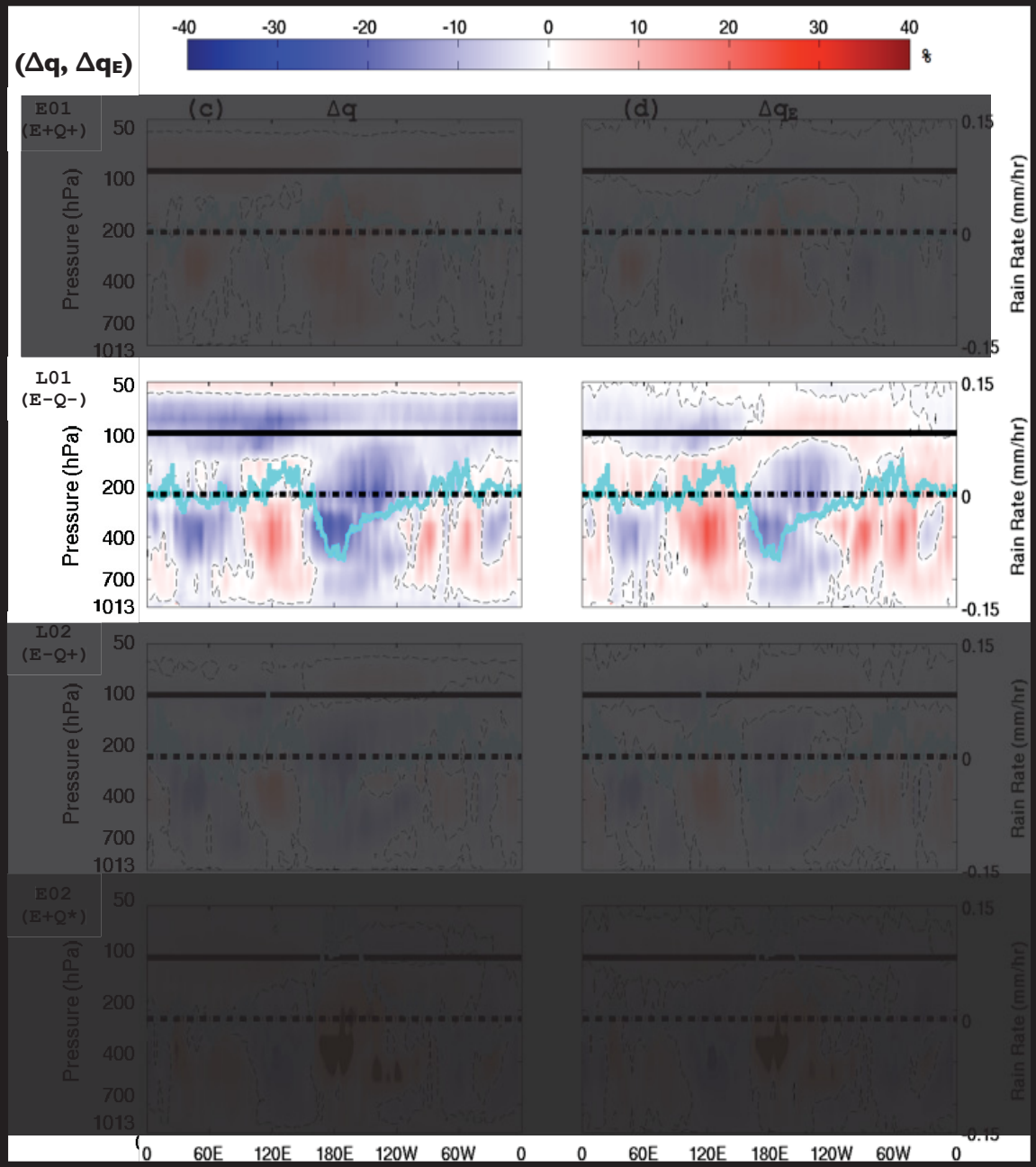

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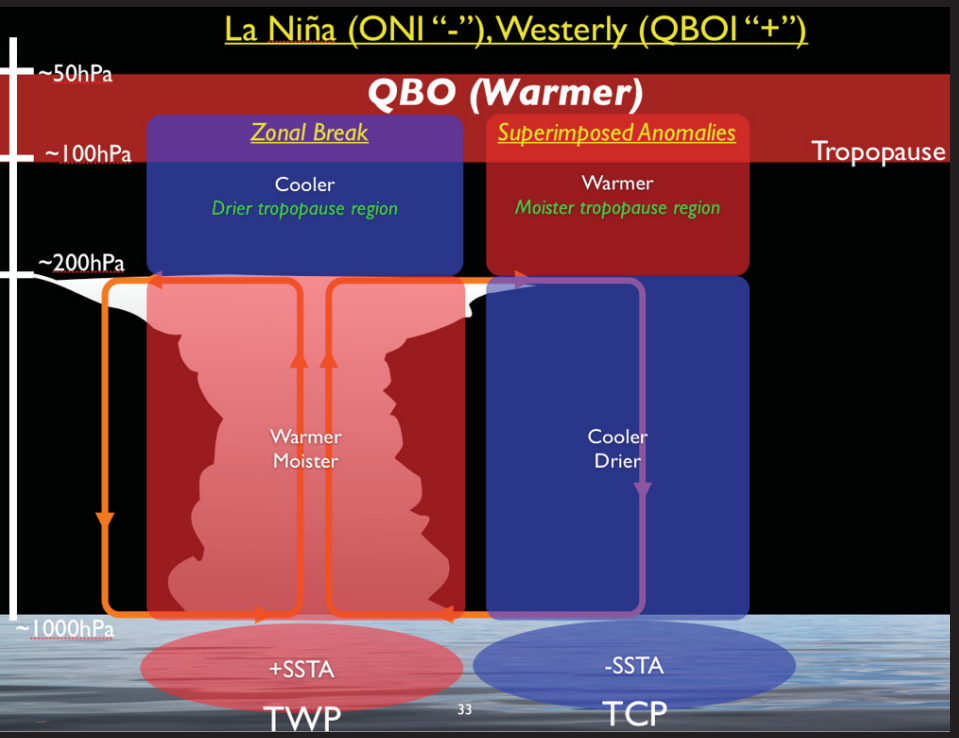
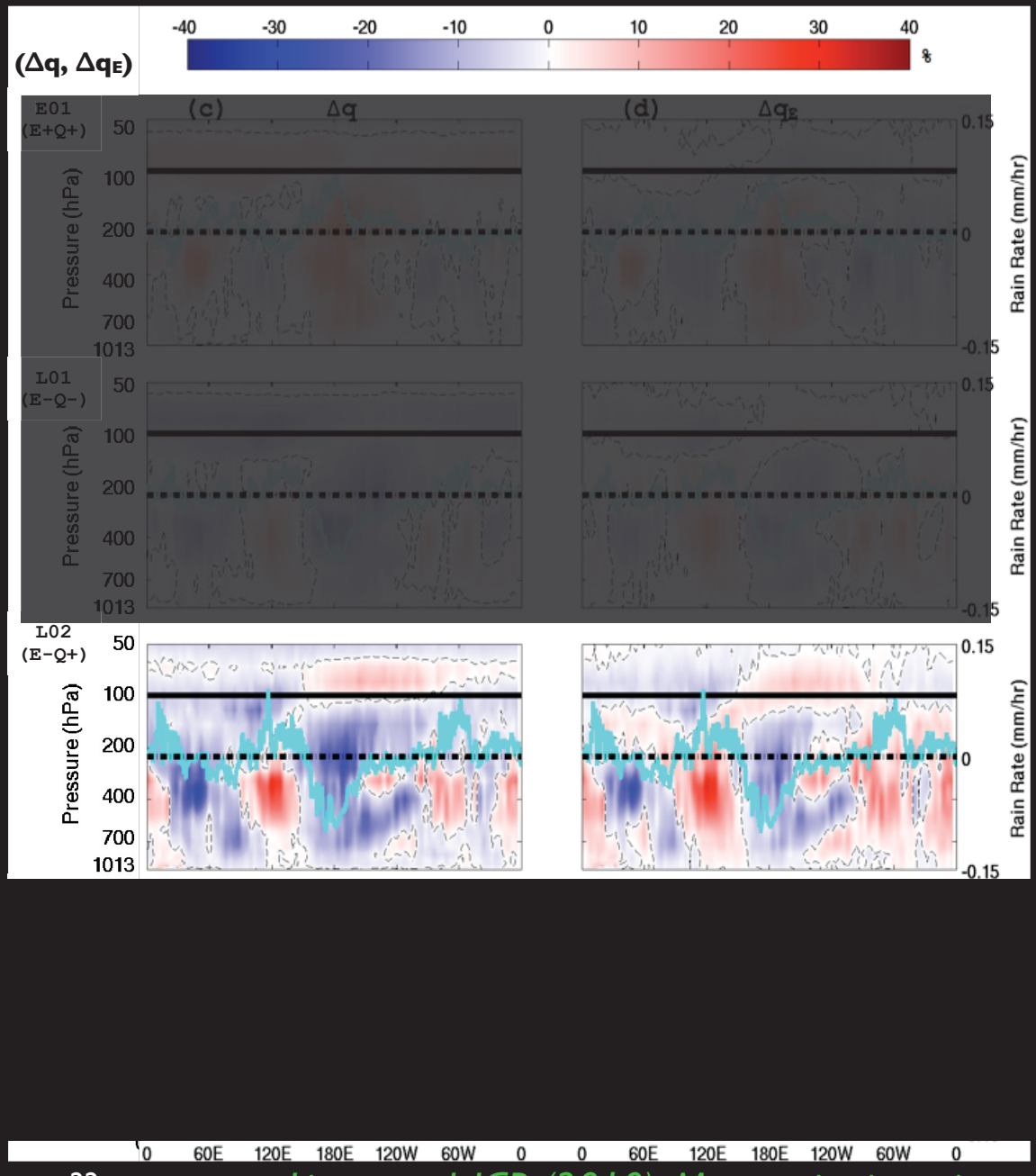
Vertical and Zonal Structure of ΔT and Δq





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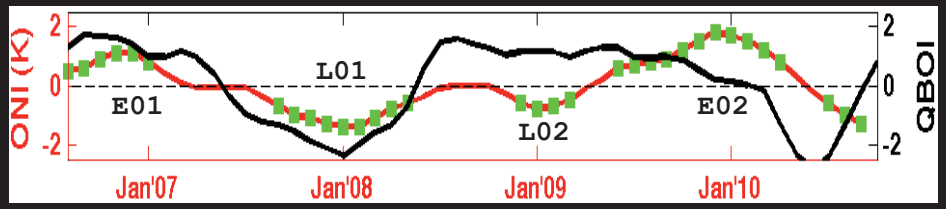
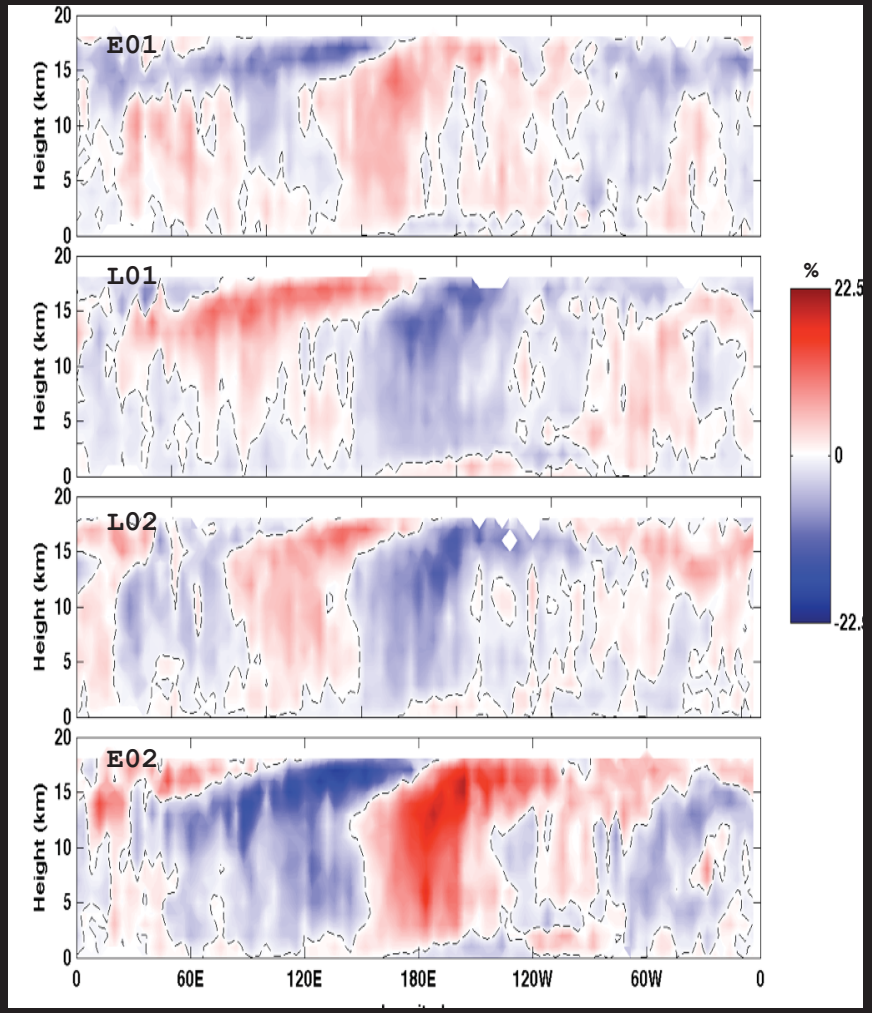
Liang, et.al, JGR (2010), Manuscript in review

Clouds (8S-8N)

August 2006-November 2010

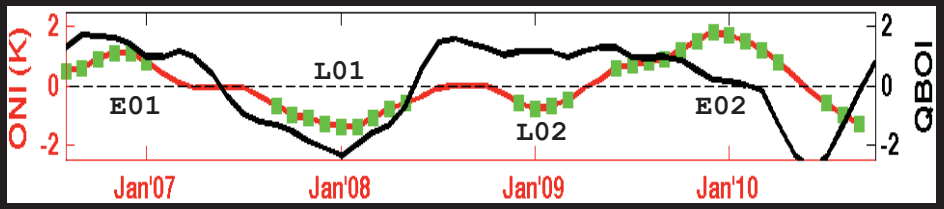
All Clouds (CloudSat + CALIPSO) (1)

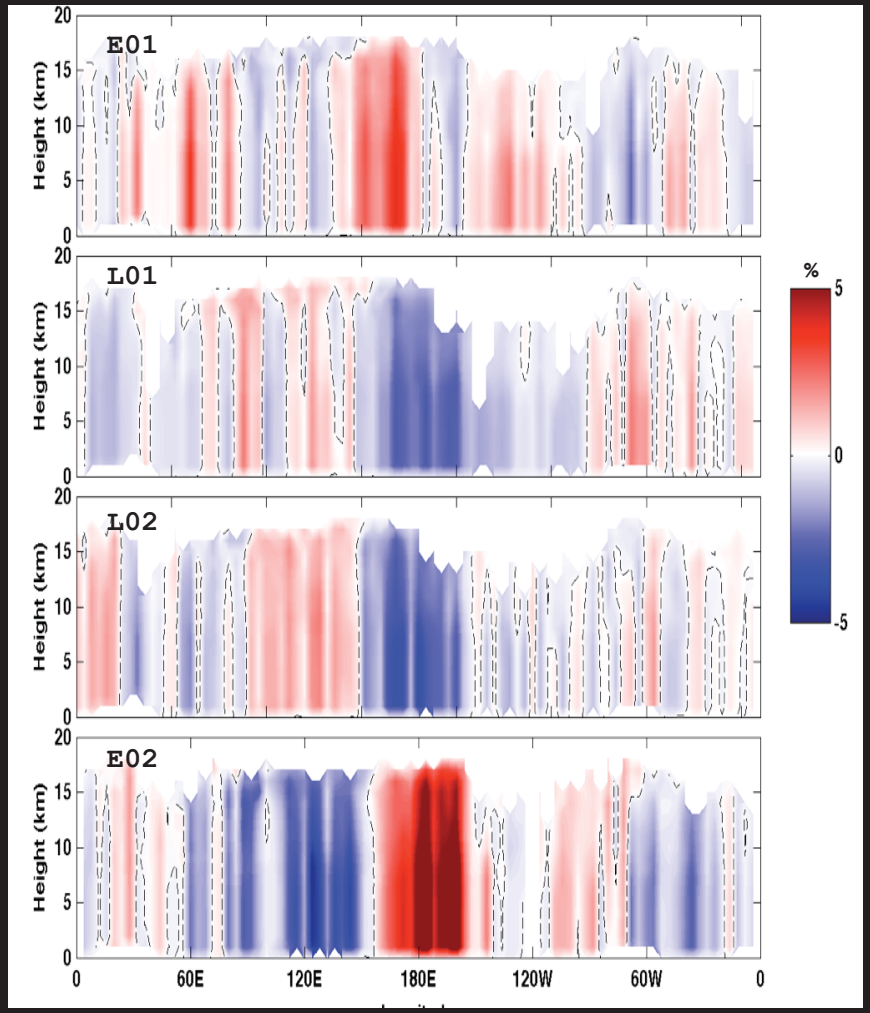




- Strong ENSO impact on total tropical cloud distribution.
- Vertical anomalies in free troposphere and upper troposphere. TTL shows eastward slanted anomalies

Cumulonimbus (CloudSat) (2)





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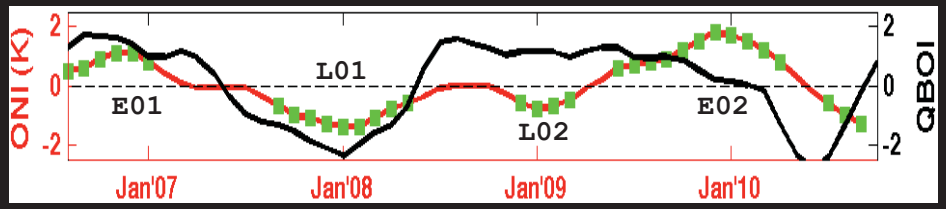
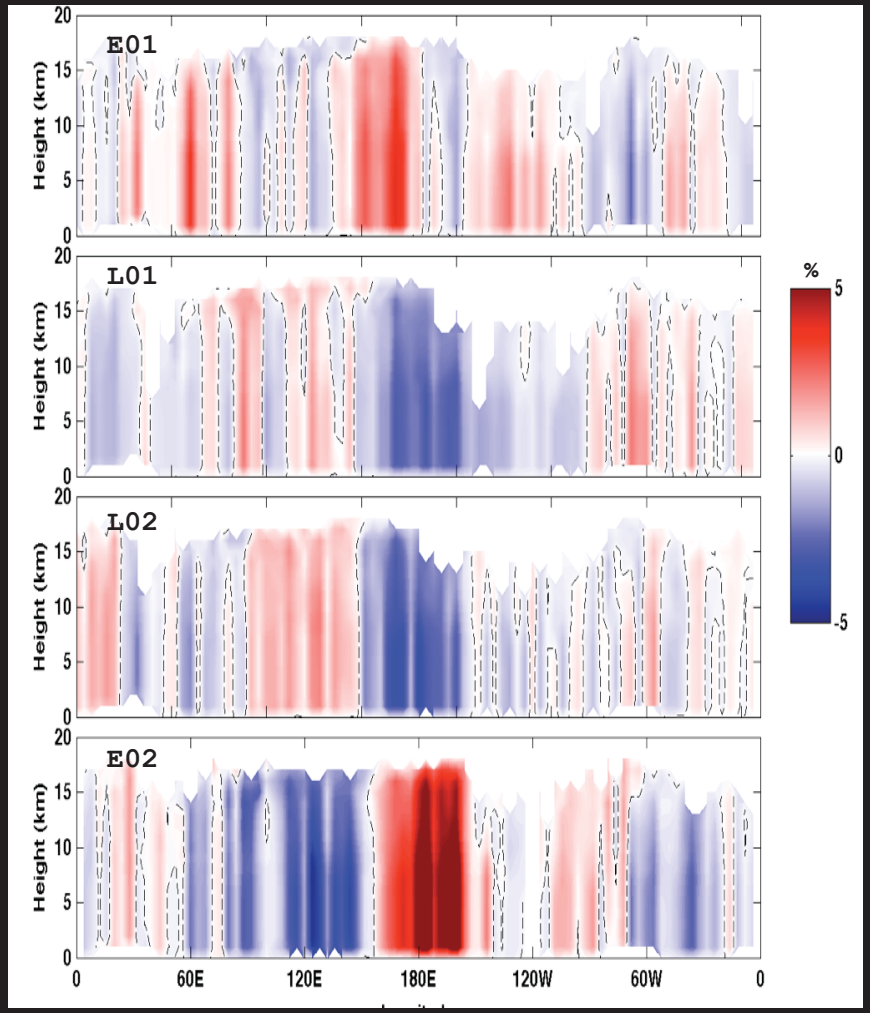
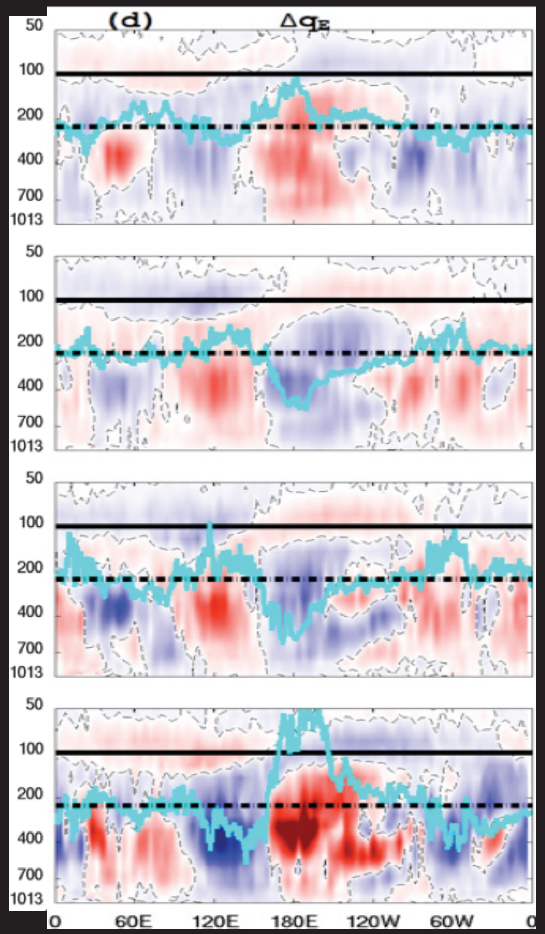
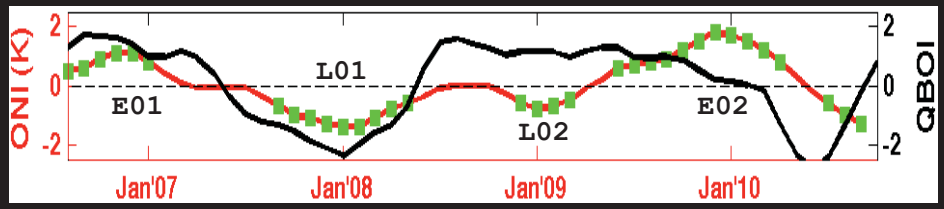


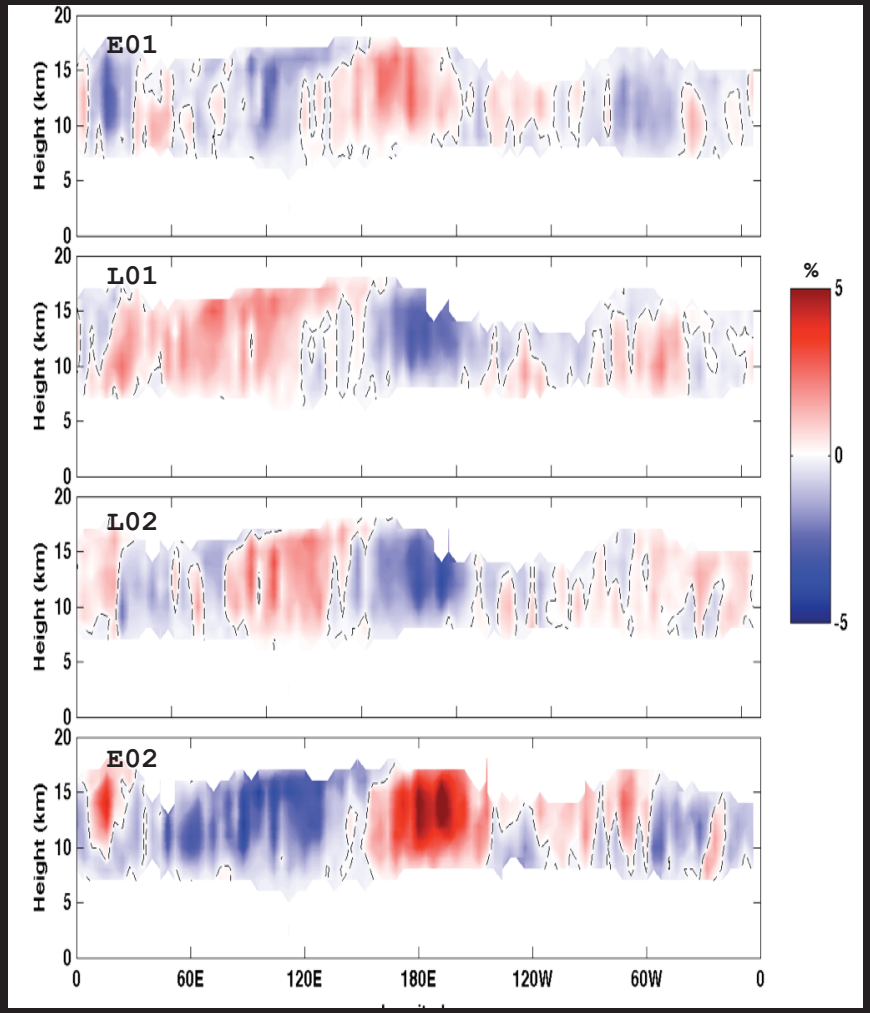




Deep clouds follow vertical structure of Δq

Cirrus (CloudSat) (3)

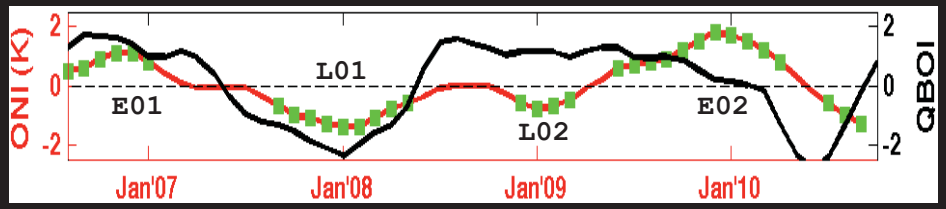


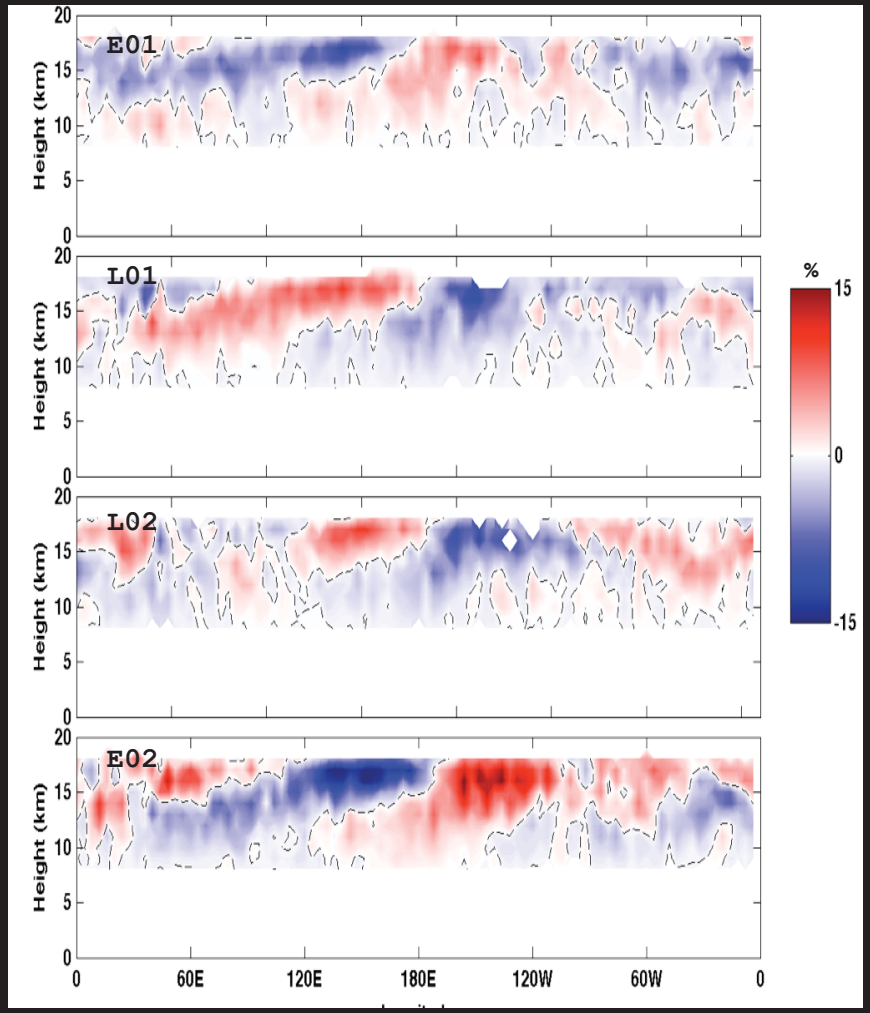


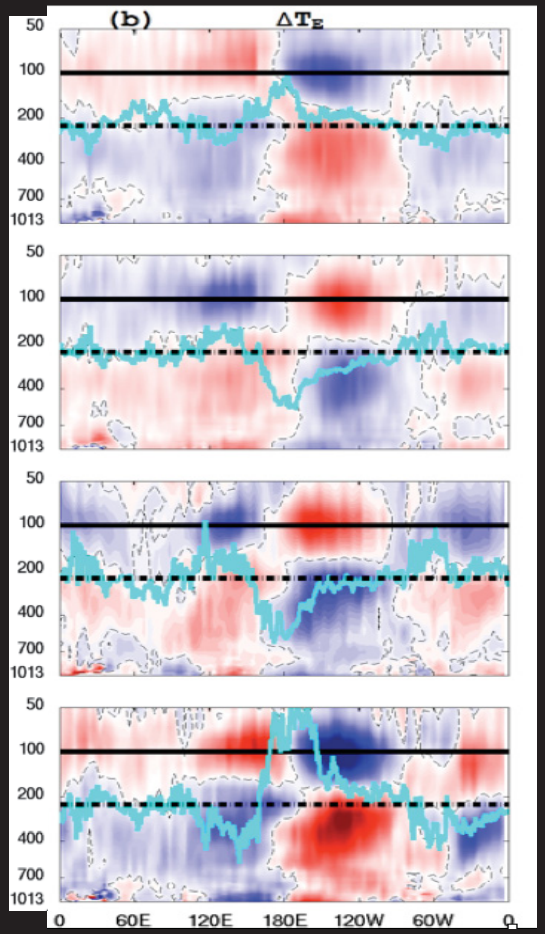
- Thick cirrus anomalies mimic the deep convective clouds.
- CFO are about the same because these clouds are detrained from deep convection.

Cirrus (CALIPSO)

(4)







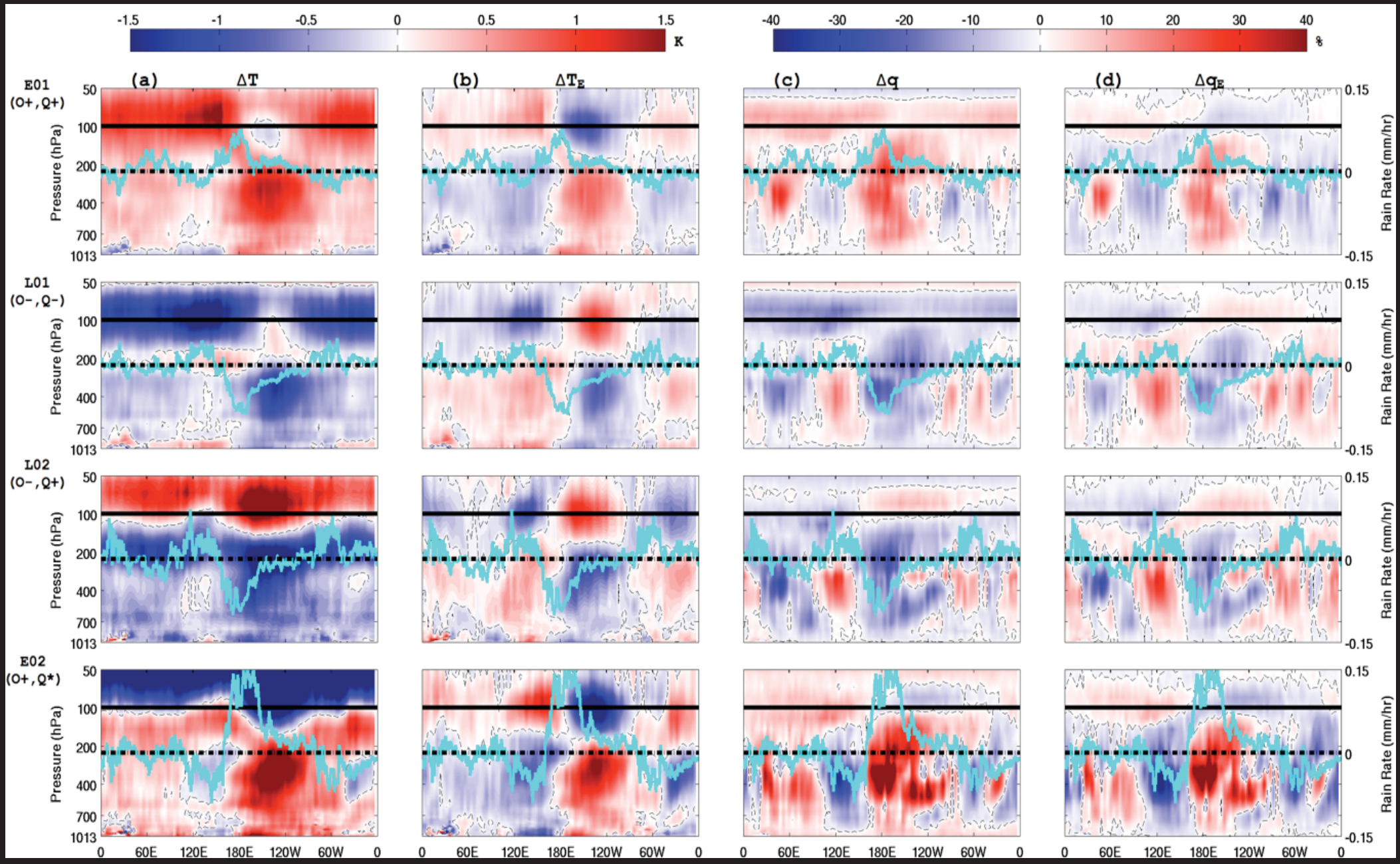
High thin cirrus have eastward slanting anomalies due to ΔT

Conclusion

- TTL T and H_2O anomalies show a location dependent zonal break depending on the relative phase of the ENSO and QBO. Migration of convection is one mechanism responsible for this.
- Evidence of joint ENSO and QBO impact on zonal water vapor distribution; TCP might play a role.
- ENSO signature is strong on high clouds (strong for low clouds too (not shown)). Still need to investigate possible QBO signature on high clouds. Need longer time series!
- Thin cirrus (CALIPSO) clouds closely follow T anomalies. Deep cloud ENSO signature consistent with H_2O changes.
- ***Combined A-Train soundings can be used to assess climate models and process representation of humidity.***
- ***Cloud profiles enable us to better characterize possible cloud feedback mechanisms for different cloud types.***

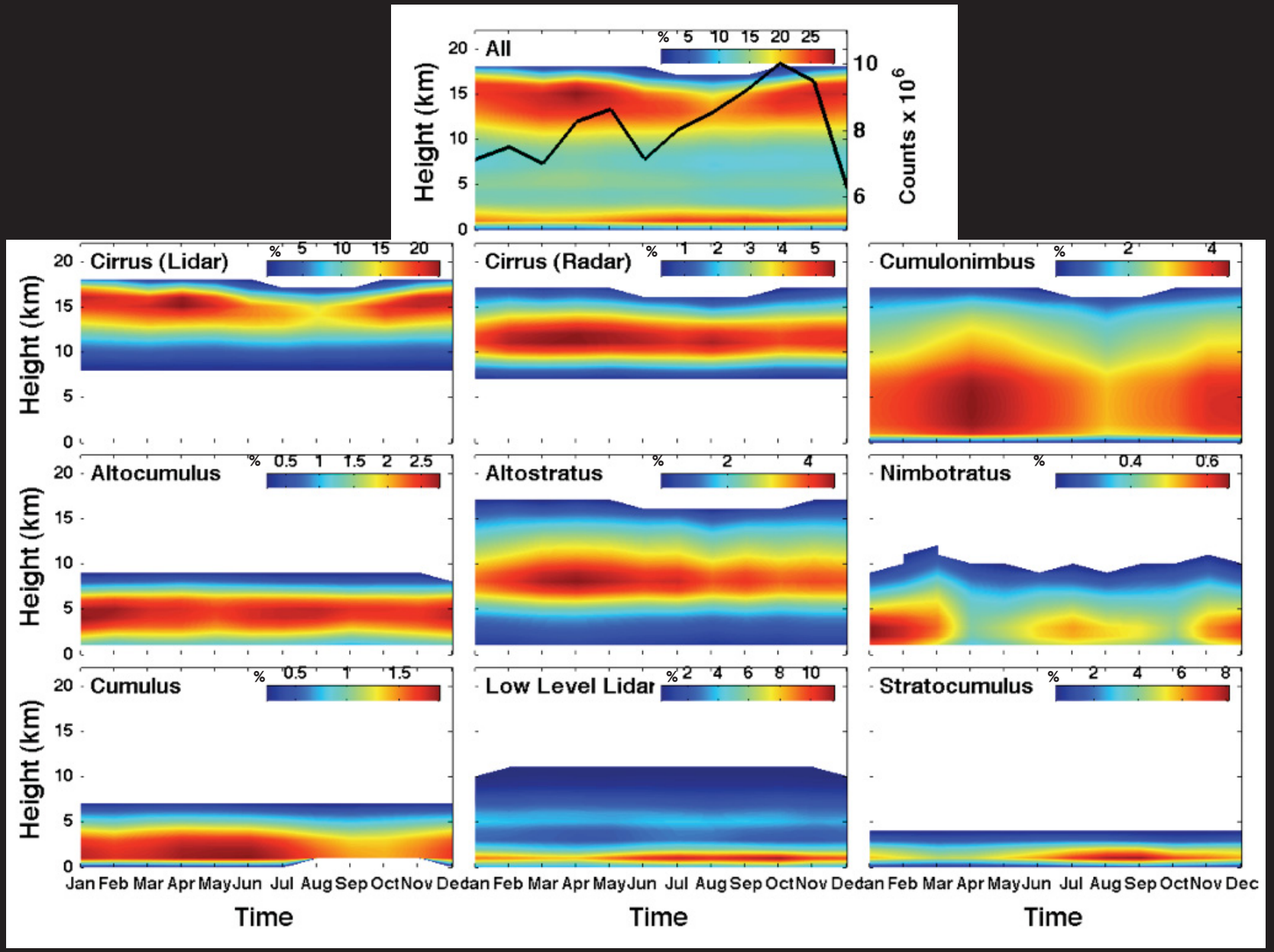
Thank You!!!

Vertical and Zonal Structure of ΔT and Δq



Liang, et.al, JGR (2010), Manuscript in review

Annual Cycle of Cloud Frequency (CFO) of Occurrence (%) by Type



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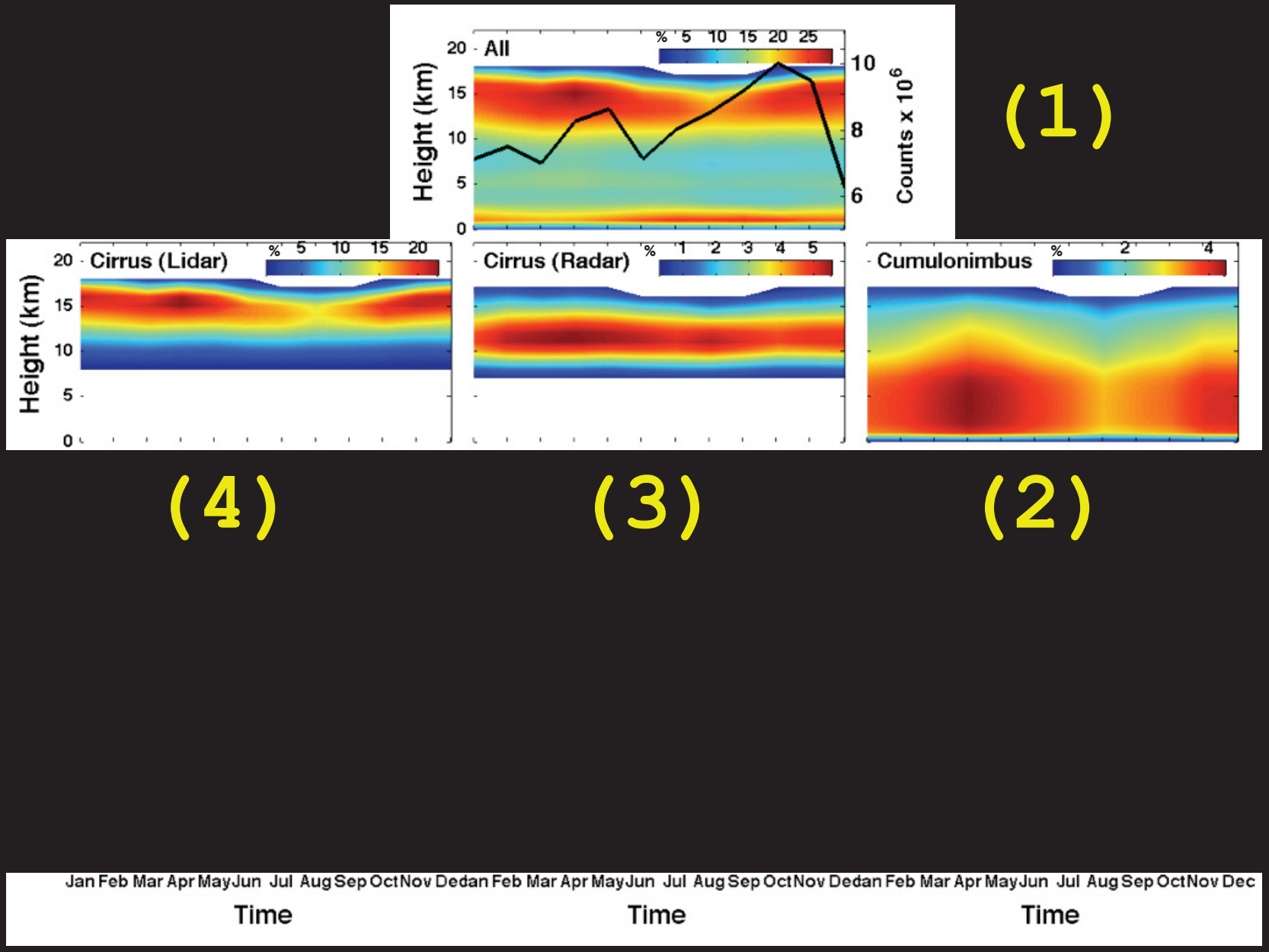

(1)

(4) (3) (2)